ELECTRIC VEHICLE RESEARCH, DEVELOPMENT, AND DEMONSTRATION ACT OF 1975

HEARINGS

BEFORE THE

SPECIAL SUBCOMMITTEE ON SCIENCE, TECHNOLOGY, AND COMMERCE

OF THE

COMMITTEE ON COMMERCE

UNITED STATES SENATE

NINETY-FOURTH CONGRESS

FIRST SESSION

ON

S. 1632 and H.R. 8800

TO AUTHORIZE IN THE ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION A FEDERAL PROGRAM OF RESEARCH, DEVELOPMENT, AND DEMONSTRATION DESIGNED TO PROMOTE ELECTRIC VEHICLE TECHNOLOGIES AND TO DEMONSTRATE THE COMMERCIAL FEASIBILITY OF ELECTRIC VEHICLES

OCTOBER 7 AND 10, 1975

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ELECTRIC VEHICLE RESEARCH, DEVELOPMENT, AND DEMONSTRATION ACT OF 1975

TUESDAY, OCTOBER 7, 1975

U.S. SENATE,
COMMITTEE ON COMMERCE, SPECIAL
SUBCOMMITTEE ON SCIENCE, TECHNOLOGY, AND COMMERCE,
Washington, D.C.

The subcommittee met at 9:35 a.m. in room 1318, Dirksen Senate Office Building, Hon. Frank E. Moss presiding.

OPENING STATEMENT BY SENATOR MOSS

Senator MOSS. The subcommittee will come to order.

The special Subcommittee on Science, Technology, and Commerce is now beginning 2 days of hearings on the electric vehicle legislation. These hearings are a reflection of the growing belief in the Congress that the electric vehicle is an extremely important option to consider as we attempt to reduce our deepening dependence on foreign oil.

Already almost 40 percent of our oil is imported. Nearly 25 percent of it comes from the Middle East. This growing dependence presents a clear threat to our national security and a continuing drain on our economy. It will be impossible to lessen this dependence unless we halt or reverse the ever-escalating consumption of our petroleum resources. To accomplish this purpose we must focus on the automobile, for it is the single largest end-user of petroleum in this country. In fact, our motor vehicles consume approximately 6½ million barrels of petroleum a day, which is equivalent to our total present import of oil from all foreign sources.

Furthermore, there is mounting evidence that gasoline consumption will increase unless strong conservation measures are implemented.

The electric vehicle appears to provide an excellent means by which to reverse this trend. It has been estimated that, for example, if 19 percent of our cars were replaced by electric vehicles, this would save us the equivalent of approximately 365 million barrels of oil annually, almost one-sixth of our present oil imports. Also the electric vehicle provides us the option of utilizing multiple sources of energy. We could, therefore, depend on electricity generated by our coal, solar, geothermal or nuclear resources and thereby lessen the pressure on domestic petroleum reserves.

Our hearings today will focus on four major questions:

First, what are the present performance characteristics of electric vehicles and to what extent can they fulfill our current transportation needs?

Staff member assigned to these hearings: Daniel Jaffe.

Second, what are the best estimates of the probable improvements in electric vehicle performances as an outgrowth of an accelerated research and development program?

Third, what are the institutional or other barriers to rapid development and introduction of electric vehicles in our automobile fleet?

And, fourth, what should be the role of the Federal Government in facilitating electric vehicle development and demonstration?

There are two significant pieces of legislation before the subcommittee which will aid us in focusing on these questions. They are S. 1632 and H.R. 8800. Both entitled the Electric Vehicle Research, Development, and Demonstration Act of 1975.

I introduced S. 1632 with Senator Humphrey last spring and H.R. 8800 passed the House of Representatives on the 5th of September. These bills will substantially increase the Federal role in fostering electric vehicle research and development. They also, would institute a national program to demonstrate present and future electric vehicle technology to help accelerate their rapid introduction into our vehicle fleet.

[The bills and agency comments follow:]

94TH CONGRESS
1ST SESSION

S. 1632

IN THE SENATE OF THE UNITED STATES

MAY 5 (legislative day, APRIL 21), 1975

Mr. MOSS (for himself and Mr. HUMPHREY) introduced the following bill; which was read twice and referred to the Committee on Commerce

A BILL

To authorize in the Energy Research and Development Administration a Federal program of research, development, and demonstration designed to promote electric vehicle technologies and to demonstrate the commercial feasibility of electric vehicles.

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled,

SHORT TITLE

SECTION 1. This Act may be cited as the "Electric Vehicle Research, Development, and Demonstration Act of 1975".

FINDINGS

SEC. 2. The Congress hereby finds that—

(1) travel patterns of commercial and private

vehicles in urban areas are weighted heavily toward short and predictable trips well within the capability of electric vehicles of current design;

(2) our balance of payments and our economic stability are threatened by the need to import oil for the production of liquid fuel for gasoline-powered vehicles;

(3) the shortage of fuel for gasoline-powered vehicles will continue indefinitely;

(4) the increased price of petroleum is a major factor in recent inflationary trends;

(5) the strain on individuals' budgets inflicted by liquid fuel prices mandates the development of an alternative source of propulsion wherever possible;

(6) environmental pollution control is becoming more and more difficult and expensive with the use of gasoline-powered vehicles, and the steadily increasing numbers of such vehicles threatens the quality of the air even when strict controls are applied to individual vehicles;

(7) stationary sources of pollutants are potentially easier to control than moving vehicles, making it environmentally desirable for transportation systems to be powered from central sources;

(8) liquid-fuel-powered vehicles are a major source of urban noise pollution;

(9) electric-powered vehicles do not emit any significant pollutants and are far less noisy than conventional automobiles and trucks;

(10) new technologies of propulsion and control have made electric vehicles more practicable than in the past, and developments in battery technology indicate that further progress is likely in the next decade;

(11) because electric vehicles use little or no energy when stopped in urban traffic, they permit the conservation of energy currently wasted by conventional automobiles and trucks;

(12) the power demands of electric vehicles would promote energy conservation by loading utilities in off-peak late night hours, permitting more efficient use of plant capacity;

(13) the depressed state of the current automobile industry would be alleviated by the introduction of new technologies more closely matching consumer needs; and

(14) because of the large capital needs of new transportation technology, and the built-in features of current highway and maintenance systems which tend to bias

consumers toward conventional vehicles, a Federal role is required in promoting the development of the socially desirable electric vehicle industry.

POLICY AND GOALS

SEC. 3. (a) It is declared to be the policy of the United States and the purpose of this Act to demonstrate the commercial feasibility of electric vehicles for urban individual and business use, and to encourage research and development in new technologies for electric vehicles with wider applications, in order to promote long-range conservation of liquid fuel and reduce environmental pollution.

(b) In carrying out the purpose of this Act it is the goal of the Federal Government—

(1) to promote the substitution of electric vehicles for many gasoline- and diesel-powered vehicles currently used in routine short-haul, low load applications;

(2) to implement this policy by removing institutional barriers to such substitution where otherwise practicable;

(3) to provide incentives for consumers and industry to adopt and utilize electric vehicles whenever the use of such vehicles would be beneficial; and

(4) to provide a research and development background for further applications as rapidly as possible to meet the further tightening of liquid fuel availability.

DEFINITIONS

SEC. 4. For purposes of this Act—

(1) The term "electric vehicle" means a vehicle which is powered primarily by an electric motor drawing current from rechargeable storage batteries, fuel cells, or other portable sources of electrical current. It may include also a nonelectrical source of power designed to charge batteries or provide auxiliary power to the wheels.

(2) The term "project" means the Electric Vehicle Research Development and Demonstration Project established within the Energy Research and Development Administration as provided in section 5 of this Act.

(3) The term "Administrator" means the Administrator of the Energy Research and Development Administration.

(4) The term "significant numbers" means numbers sufficient to assure a realistic and effective demonstration in support of the objectives of this Act; except that in any event, for the purposes of subsection (a) of section 7, significant numbers of vehicles shall be considered to have been produced if five thousand or more are produced.

SEC. 5. (a) The Administrator shall promptly establish, as an organizational entity within the Energy Research and Development Administration, the Electric Vehicle Research, Development and Demonstration Project.

(b) The overall management of the project shall be the

responsibility of the Administrator, but he may enter into such arrangements and agreements with the National Aeronautics and Space Administration, the Secretary of Transportation, the National Science Foundation, the Environmental Protection Agency, the Secretary of Housing and Urban Development, and such other Federal offices and agencies as he may deem necessary or appropriate for the conduct by them of parts or aspects of the project which are within their particular competence.

(c) In providing for the effective management of the project the Administrator shall have specific responsibility for—

(1) promoting basic research on electric vehicle batteries, controls, and motors;

(2) determining optimum overall electric vehicle design;

(3) conducting demonstrations of the feasibility of commercial electric vehicles by contracting for the practical manufacture of electric vehicles and by developing arrangements with other agencies and nongovernmental entities for the operation of such vehicles;

(4) ascertaining consumer needs and desires so as to match the design of electric vehicles to their potential market; and

(5) ascertaining the long-term changes in road

design, urban planning, traffic management, maintenance facilities, utility rate structures, and tax policies which are needed to facilitate the manufacture and use of electric vehicles.

RESEARCH AND DEVELOPMENT

SEC. 6. The Administrator, acting through appropriate agencies and contractors, shall initiate and provide for the conduct of research and development in areas related to electric vehicles, including—

(1) energy storage technology, including batteries and their potential for convenient recharging;

(2) vehicle control systems and overall design for energy conservation, including the use of regenerative braking;

(3) urban design and traffic management for optimum transportation-related energy use and minimum transportation-related degradation of the environment; and

(4) vehicle design for maximum practical lifetime, ease of repair, and interchangeability and replaceability of parts.

DEMONSTRATION

SEC. 7. (a) The Administrator shall enter into such contracts as may be necessary and appropriate—

(1) for the production, within eighteen months

after the date of the enactment of this Act, of significant numbers of urban passenger and commercial vehicles (meeting the standards and criteria developed under subsection (b)) which have electric propulsion systems on conventional chassis; and

(2) for the production, within three years after such date, of significant number of urban passenger and commercial vehicles (meeting such standards) which are specifically designed for electric propulsion as the primary power source.

(b) Within one hundred and eighty days after the date of the enactment of this Act, the Administrator shall develop or arrange for the development of performance standards and criteria which are suitable for the needs of urban private passenger vehicles and urban commercial vehicles (and which shall be applicable to the vehicles produced under subsection (a)). The standards and criteria so developed shall not be designed simply to reflect the characteristics of current internal combustion engine automobiles and trucks, but shall also take into account the factors of energy conservation, urban traffic characteristics, patterns of use for "second" vehicles, consumer preferences, maintenance needs, battery recharging characteristics, materials demand and recyclability, vehicle safety and insurability, and other relevant considerations, as such factors and considerations par-

ticularly apply to or affect vehicles with electric propulsion systems. Such standards and criteria are to be developed and determined separately for vehicles designed with electric propulsion systems on conventional chassis and for vehicles specifically designed for electric propulsion as the primary power source. In developing such standards and criteria, the Administrator shall consult with appropriate authorities concerning design needs for electric vehicles compatible with long-range urban planning and traffic management.

(c) The Administrator shall make such arrangements as may be necessary or appropriate—

(1) for the introduction of the electric vehicles produced under subsection (a) into the vehicle fleets of State and local governments and Federal agencies;

(2) for the introduction of such vehicles into individual and business use, with the individuals and businesses involved being chosen by an equitable process (such as a lottery in each region or category) and being given the option of purchasing or leasing such vehicles under terms and conditions which will insure their widespread use;

(3) for the evaluation of electric vehicle performance and of consumer reaction to electric vehicles in use:

(4) for demonstration maintenance projects (including maintenance organization and equipment

needs), and model training projects on maintenance procedures; and

(5) for the dissemination of data on electric vehicle safety and operating characteristics (including non-technical descriptive data made available through the Government Printing Office) to State and municipal consumer affairs agencies and groups.

USE OF ELECTRIC VEHICLES BY FEDERAL AGENCIES

SEC. 8. (a) The United States Postal Service, the General Services Administration, the Secretary of Defense, and the heads of other Federal agencies shall arrange for the introduction of electric vehicles into their fleets as soon as possible. For competitive procurement purposes in purchasing such vehicles, life cycle costing and the beneficial emission characteristics of electric vehicles shall be fully taken into account. In any case where (as determined by the head of the agency involved) electric vehicles are practical but are not economically competitive with conventional vehicles, the Administrator may pay the incremental cost of the electric vehicles (as a part of the demonstration program under section 7) to insure that the maximum number of electric vehicles are placed in use by Federal agencies.

INCENTIVES AND ASSESSMENTS

SEC. 9. (a) The Administrator shall conduct a study to determine the existence of any tax, regulatory, traffic,

urban design, and other institutional factors which tend or may tend to bias transportation systems toward vehicles particular characteristics, and shall report the results of such study to the Congress within six months after the date of the enactment of this Act.

(b) The Administrator shall conduct a continuing assessment of the long-range materials demand and pollution effects which may result from or in connection with the electrification of urban traffic, and shall include a statement of his current findings in each report submitted under section 12. Any environmental impact statement which may be filed under a Federal law with respect to research, development, or demonstration activities under this Act shall include reference to the matters which are subject to assessment under this subsection.

(c) In carrying out his functions under this Act, the Administrator shall perform or cause to be performed studies and research on incentives to promote broader utilization and consumer acceptance of electric vehicle technologies.

ENCOURAGEMENT AND PROTECTION OF SMALL BUSINESS

SEC. 10. In carrying out his functions under this Act, the Administrator shall take steps to assure that small business concerns and qualified individuals will have realistic and adequate opportunities to participate in the program under this Act to the maximum extent possible.

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REPORTS TO CONGRESS

SEC. 11. The Administrator shall submit to the Congress semiannually a report on all activities being undertaken or carried out pursuant to the provisions of this Act, including such projections and estimates as may be necessary to evaluate the progress of the program under this Act and to indicate the extent to which and pace at which the objectives of this Act are being achieved. Each such report shall also include any recommendations which the Administrator may deem appropriate for legislation or related action which might further the purposes of this Act.

APPROPRIATIONS

SEC. 12. There are authorized to be appropriated to the Administrator not to exceed $40,000,000 for each of the three fiscal years 1976, 1977, and 1978. Any amount appropriated pursuant to this section shall remain available until expended, and any amount authorized for either of the first two such fiscal years but not appropriated may be appropriated for any succeeding fiscal year through the third such year.

94TH CONGRESS 1ST SESSION **H. R. 8800**

IN THE SENATE OF THE UNITED STATES

SEPTEMBER 8, 1975

Read twice and referred to the Committee on Commerce

AN ACT

To authorize in the Energy Research and Development Administration a Federal program of research, development, and demonstration designed to promote electric vehicle technologies and to demonstrate the commercial feasibility of electric vehicles.

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled,

SHORT TITLE

SECTION 1. This Act may be cited as the "Electric Vehicle Research, Development, and Demonstration Act of 1975".

FINDINGS

SEC. 2. The Congress hereby finds that—

II

(1) travel patterns of commercial and private vehicles in urban areas are weighted heavily toward short and predictable trips well within the capability of electric vehicles;

(2) travel patterns of motor vehicles used on farms for agricultural production and rural travel, including automobiles, tractors, and trucks, in many applications are within the capability of electric vehicles;

(3) our balance of payments and our economic stability are threatened by the need to import oil for the production of liquid fuel for gasoline-powered vehicles;

(4) the shortage of fuel for gasoline-powered vehicles will continue indefinitely;

(5) the increased price of petroleum is a major factor in recent inflationary trends;

(6) the strain on individuals' budgets inflicted by liquid fuel prices mandates the development of an alternative source of propulsion wherever possible;

(7) the potential negative impact of continued motor vehicle fuel price increases on farm production mandates the development of alternate sources of farm vehicle propulsion whenever possible;

(8) environmental pollution control is becoming more and more difficult and expensive with the use of

gasoline-powered vehicles, and the steadily increasing numbers of such vehicles threaten the quality of the air even when strict controls are applied to individual vehicles;

(9) stationary sources of pollutants are potentially easier to control than moving vehicles, making it environmentally desirable for transportation systems to be powered from central sources;

(10) liquid-fuel-powered vehicles are a major source of urban noise pollution;

(11) electric-powered vehicles do not emit any significant pollutants and are far less noisy than conventional automobiles and trucks;

(12) new technologies of propulsion and control have made electric and hybrid vehicles more practicable than in the past, and developments in battery technology indicate that further progress is likely in the next decade;

(13) because electric and hybrid vehicles use little or no energy when stopped in urban traffic, they permit the conservation of energy currently wasted by conventional automobiles and trucks;

(14) the power demands of electric and hybrid vehicles would promote energy conservation by loading utilities in off-peak late night hours, permitting more efficient use of plant capacity;

(15) the depressed state of the current automobile industry would be alleviated by the introduction of new technologies more closely matching consumer needs; and

(16) because of the large capital needs of new transportation technology, and the built-in features of current highway and maintenance systems which tend to bias consumers toward conventional vehicles, a Federal role is required in promoting the development of the socially desirable electric and hybrid vehicle industry.

POLICY AND GOALS

SEC. 3. (a) It is declared to be the policy of the United States and the purpose of this Act to demonstrate the commercial feasibility of electric and hybrid vehicles for urban individual and business use and farm applications, and to encourage research and development in new technologies for electric and hybrid vehicles with wider applications, in order to promote long-range conservation of liquid fuel and reduce environmental pollution.

(b) In carrying out the purpose of this Act it is the goal of the Federal Government—

(1) to promote the substitution of electric and hybrid vehicles for many gasoline- and diesel-powered vehicles currently used in routine short-haul, low-load applications;

(2) to implement this policy by removing institutional barriers to such substitution where otherwise practicable;

(3) to provide incentives for consumers and industry to adopt and utilize electric and hybrid vehicles whenever the use of such vehicles would be beneficial; and

(4) to provide a research and development background for further applications as rapidly as possible to meet the further tightening of liquid fuel availability.

DEFINITIONS

SEC. 4. For the purposes of this Act—

(1) The term "electric vehicle" means a vehicle which is powered by an electric motor drawing current from rechargeable storage batteries, fuel cells, or other portable sources of electrical current, and which may include also a nonelectrical source of power designed to charge batteries.

(2) The term "hybrid vehicle" means a vehicle propelled by a combination of an electric motor and an internal combustion engine or other alternative engine.

(3) The term "project" means the Electric Vehicle Research, Development, and Demonstration Project established within the Energy Research and Development Administration as provided in section 5.

(4) The term "Administrator" means the Administra-

tor of the Energy Research and Development Administration.

(5) The term "commercial electric vehicles" in section 7 includes motor vehicles used for business purposes on farms, such as tractors and trucks, for agricultural production and rural travel, in addition to vehicles used for commercial purposes in urban areas.

MANAGEMENT

SEC. 5. (a) The Administrator shall promptly establish, as an organizational entity within the Energy Research and Development Administration, the Electric Vehicle Research, Development, and Demonstration Project.

(b) The overall management of the project shall be the responsibility of the Administrator, but he may enter into such arrangements and agreements with the National Aeronautics and Space Administration, the Secretary of Transportation, the National Science Foundation, the Environmental Protection Agency, the Secretary of Housing and Urban Development, the Secretary of Agriculture, and other Federal officers and agencies as he may deem necessary or appropriate for the conduct by them of parts or aspects of the project which are within their particular competence.

(c) In providing for the effective management of the project the Administrator shall have specific responsibility for—

(1) promoting basic and applied research on electric and hybrid vehicle batteries, controls, and motors;

(2) determining optimum overall electric and hybrid vehicle design;

(3) conducting demonstrations of the feasibility of commercial electric and hybrid vehicles by contracting for the practical manufacture of electric and hybrid vehicles and by developing arrangements with other agencies and nongovernmental entities for the operation of such vehicles;

(4) ascertaining consumer needs and desires so as to match the design of electric and hybrid vehicles to their potential market; and

(5) ascertaining the long-term changes in road design, urban planning, traffic management, maintenance facilities, utility rate structures, and tax policies which are needed to facilitate the manufacture and use of electric and hybrid vehicles.

RESEARCH AND DEVELOPMENT

SEC. 6. The Administrator, acting through appropriate agencies and contractors, shall initiate and provide for the conduct of research and development in areas related to electric and hybrid vehicles, including—

(1) energy storage technology, including batteries and their potential for convenient recharging;

(2) vehicle control systems and overall design for energy conservation, including the use of regenerative braking;

(3) urban design and traffic management for optimum transportation-related energy use and minimum transportation-related degradation of the environment; and

(4) vehicle design for maximum practical lifetime, ease of repair, and interchangeability and replaceability of parts.

DEMONSTRATION

SEC. 7. (a) The Administrator (subject to section 13 (c)) shall enter into such contracts as may be necessary and appropriate—

(1) within one year after the date of the enactment of this Act, for the production of a reasonable number of urban passenger and commercial electric vehicles for the purpose of evaluation tests and initial in-use demonstration of current state-of-the-art;

(2) within fifteen months after such date, for the production of at least twenty-five hundred select urban passenger and commercial electric vehicles (meeting the initial standards and criteria developed under subsection (b)) with available components and designs; and

(3) within forty-two months after such date, for the production of at least five thousand urban passenger and commercial electric or hybrid vehicles (meeting the appropriate standards and criteria developed under subsection (b)) which have advanced components and designs.

(b) (1) Within one year after the date of the enactment of this Act, the Administrator shall develop or arrange for the development of initial performance standards and criteria which are suitable for the needs of urban private passenger vehicles and urban commercial vehicles (and which shall be applicable to the vehicles produced under subsection (a) (2)). The standards and criteria so developed shall not be designed simply to reflect the characteristics of current internal combustion engine automobiles and trucks, but shall also take into account the factors of energy conservation, urban traffic characteristics, patterns of use for "second" vehicles, consumer preferences, maintenance needs, battery recharging characteristics, agricultural requirements, materials demand and recyclability, vehicle safety and insurability, and other relevant considerations, as such factors and considerations particularly apply to or affect vehicles with electric or hybrid propulsion systems. Such standards and criteria are to be developed and determined utilizing the best current state-of-the-art and utilizing the state-of-the-art that

would be projected to result from the research and development program described in section 6. These performance standards and criteria shall be revised periodically as the state-of-the-art improves. In developing such standards and criteria, the Administrator shall consult with appropriate authorities concerning design needs for electric and hybrid vehicles compatible with long-range urban planning, traffic management, and vehicle safety.

(2) Before entering into contracts for the production of vehicles under subsection (a) (3), the Administrator shall transmit to the Speaker of the House of Representatives and the President of the Senate and to the Committee on Science and Technology of the House of Representatives and the Committee on Commerce of the Senate a full and complete statement of the standards and criteria developed under paragraph (1) as revised and currently in effect.

(c) The Administrator shall make such arrangements as may be necessary or appropriate—

(1) for the introduction of the electric and hybrid vehicles produced under subsection (a) into the vehicle fleets of State and local governments and Federal agencies;

(2) for the introduction of such vehicles into individual and business use, including farms, with the individuals and businesses involved being chosen by an equitable process (such as a lottery in each region or

category) and being given the option of purchasing or leasing such vehicles under terms and conditions which will insure their widespread use;

(3) for the evaluation of electric and hybrid vehicle performance and of consumer reaction to electric and hybrid vehicles in use;

(4) for demonstration maintenance projects (including maintenance organization and equipment needs), and model training projects on maintenance procedures; and

(5) for the dissemination of data on electric and hybrid vehicle safety and operating characteristics (including nontechnical descriptive data made available through the Government Printing Office) to State and municipal consumer affairs agencies and groups, and Federal, State, and local farm and rural agencies and groups.

(d) Every contract entered into pursuant to this section shall be subject to the provisions of the Buy American Act (41 U.S.C. 10a through 10d) and contain the provision required by the Act for public works.

USE OF ELECTRIC AND HYBRID VEHICLES BY FEDERAL AGENCIES

SEC. 8. The United States Postal Service, the General Services Administration, the Secretary of Defense,

and the heads of other Federal agencies shall arrange for the introduction of electric and hybrid vehicles into their fleets as soon as possible. For competitive procurement purposes in purchasing such vehicles, life cycle costing and the beneficial emission characteristics of electric and hybrid vehicles shall be fully taken into account. In any case where (as determined by the head of the agency involved) electric or hybrid vehicles are practical but are not economically competitive with conventional vehicles, the Administrator may pay the incremental cost of the electric or hybrid vehicles (as part of the demonstration program under section 7) to insure that the maximum number of electric and hybrid vehicles are placed in use by Federal agencies.

INCENTIVES AND ASSESSMENTS

SEC. 9. (a) The Administrator shall conduct a study to determine the existence of any tax, regulatory, traffic, urban design, rural electrical and other institutional factors which tend or may tend to bias surface transportation systems toward vehicles of particular characteristics, and shall report the results of such study to the Congress within one year after the date of the enactment of this Act.

(b) The Administrator shall conduct a continuing assessment of the long-range materials demand and pollution effects which may result from or in connection with the electrification of urban traffic, and shall include a statement of his current findings in each report submitted under section

12. Any environmental impact statement which may be filed under a Federal law with respect to research, development, or demonstration activities under this Act shall include reference to the matters which are subject to assessment under this subsection.

(c) In carrying out his functions under this Act, the Administrator shall perform or cause to be performed studies and research on incentives to promote broader utilization and consumer acceptance of electric and hybrid vehicle technologies.

(d) The Secretary of Transportation shall conduct a study on the current and future applicability of safety standards and regulations to electric and hybrid vehicles and shall report the results of such study to the Administrator and to the Congress within two hundred forty days after the date of the enactment of this Act.

ENCOURAGEMENT AND PROTECTION OF SMALL BUSINESS

SEC. 10. (a) In carrying out his functions under this Act, the Administrator shall take steps to assure that small business concerns and qualified individuals will have realistic and adequate opportunities to participate in the program under this Act to the maximum extent possible.

(b) To assist in accomplishing the objective of subsection (a), the Administrator shall reserve for contracts

with small business concerns a reasonable portion of the funds made available pursuant to this Act for purposes of section 7 (a).

(c) In addition, the Administrator—

(1) shall include in all contracts under section 7 (a) such terms, conditions, and payment schedules as may assist in meeting the special needs of small business concerns, and shall take steps to avoid the inclusion in such contracts of any terms, condition, or penalties which would tend to prevent such concerns from participating in the program under this Act; and

(2) shall make planning grants available to qualified small business concerns which require assistance in developing, submitting, and entering into such contracts.

LOAN GUARANTIES

SEC. 11. (a) It is the policy of the Congress to encourage and assist in the commercial development of electric and hybrid vehicles, and to ensure that small businesses are not excluded from participation in such development due to lack of adequate capital. Accordingly, it is the policy of the Congress to provide guaranties of loans made for such purposes.

(b) In order to encourage the commercial production of electric and hybrid vehicles, the Administrator is authorized to guarantee, and to enter into commitments to guarantee, lenders against loss of principal or interest on loans made

by such lenders to qualified borrowers, primarily small business concerns, for the purposes of—

(1) research and development related to electric and hybrid vehicle technology;

(2) prototype development for such vehicles and parts thereof;

(3) construction of capital equipment related to research on and development and production of electric and hybrid vehicles and components; or

(4) initial operating expenses associated with the development and production of electric and hybrid vehicles and components.

(c) Any guaranty under this section shall apply only to so much of the principal amount of the loan involved as does not exceed 90 per centum of the aggregate cost of the activity with respect to which the loan is made.

(d) Loan guaranties under this section shall be on such terms and conditions as the Administrator determines, except that a guaranty shall be made under this section only if—

(1) the loan bears interest at a rate not to exceed such annual per centum on the principal obligation outstanding as the Administrator determines to be reasonable, taking into account the range of interest rates prevailing in the private sector for similar loans and risks by the United States;

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(2) the terms of such loan require full repayment over a period not to exceed fifteen years;

(3) in the judgment of the Administrator, the amount of the loan (when combined with amounts available to the qualified borrower from other sources) will be sufficient to carry out the activity with respect to which the loan is made; and

(4) in the judgment of the Administrator, there is reasonable assurance of repayment of the loan by the qualified borrower.

(e) The amount of the guaranty of any loan for any single qualified borrower shall not exceed $3,000,000; and the aggregate amount of guaranties outstanding under this section at any one time shall not exceed $60,000,000.

(f) As used in this section, the term "qualified borrower" means any partnership, corporation, or other legal entity which (as determined by the Administrator) has presented satisfactory evidence of an interest in electric or hybrid vehicle technology and is capable of performing research or completing the development and production of electric or hybrid vehicles or any components thereof in an acceptable manner.

(g) (1) With respect to any loan guaranteed pursuant to this section, the Administrator (subject to section 13 (c)) is authorized to enter into a contract to pay, and to pay, the

lender for and on behalf of the borrower the interest charges which become due and payable on the unpaid balance of any such loan if the Administrator finds—

(A) that the borrower is unable to meet interest charges, that it is in the public interest to permit the borrower to continue to pursue the purposes of his project, and that the probable net cost to the Federal Government in paying such interest will be less than that which would result in the event of a default; and

(B) the amount of such interest charges which the Administrator is authorized to pay shall be no greater than the amount of interest which the borrower is obligated to pay under the loan agreement.

(2) In the event of any default by a qualified borrower on a guaranteed loan, the Administrator is authorized to make payment in accordance with the guaranty, and the Attorney General shall take such action as may be appropriate to recover the amounts of such payments (including any payment of interest under paragraph (1)) from such assets of the defaulting borrower as are associated with the activity with respect to which the loan was made or from any other surety included in the terms of the guaranty.

(h) No loan guaranties shall be made, or interest assistance contracts entered into, pursuant to this section, after

the expiration of the 5-calendar-year period following the date of the enactment of this Act.

(i) An applicant for a loan guarantee must be a citizen or national of the United States. A corporation, partnership, or association shall not be deemed a citizen of the United States unless the Administrator determines that it satisfactorily meets all the requirements of section 802 of title 46, United States Code, for determining the United States citizenship of such entities operating a vessel in the coastwise trade.

REPORTS TO CONGRESS

SEC. 12. The Administrator shall submit to the Congress semiannually a report on all activities being undertaken or carried out pursuant to the provisions of this Act, including (1) such projections and estimates as may be necessary to evaluate the progress of the program under this Act and to indicate the extent to which and pace at which the objectives of this Act are being achieved, and (2) a statement of the extent to which imported automobile chassis or components are being used, or are desirable, for the production of vehicles under section 7(a), and of the extent to which restrictions imposed by law or regulation upon the importation or use of such chassis or components are impeding the achievement of the purpose of this Act. Each

such report shall also include any recommendations which the Administrator may deem appropriate for legislation or related action which might further the purposes of this Act.

APPROPRIATIONS AND APPROPRIATION ACTS

SEC. 13. (a) There are authorized to be appropriated to the Administrator to carry out this Act (including the payment of loan guaranties and interest under section 11) not to exceed $10,000,000 for the fiscal year 1976, and the three-month transition period immediately following, not to exceed $40,000,000 for the fiscal year 1977, not to exceed $30,000,000 for the fiscal year 1978, not to exceed $60,000,000 for the fiscal year 1979, and not to exceed $20,000,000 for the fiscal year 1980. Any amount appropriated pursuant to this section shall remain available until expended, and any amount authorized for any fiscal year (or period) prior to the fiscal year 1980 but not appropriated may be appropriated for any succeeding fiscal year through the fiscal year 1980.

(b) Any moneys received by the Administrator from vehicle sales or leases (or other activities) under this Act may be retained and used by him in carrying out this Act, notwithstanding the provisions of section 3617 of the Revised Statutes (31 U.S.C. 484), and may remain available until expended; but the amount authorized to be appro-

priated for any fiscal year (or period) under subsection (a) shall be reduced by the amount of the moneys to be so received in that year (or period).

(c) The authority of the Administrator to enter into contracts under section 7 (a) or section 11 (g) (1) shall be effective for any fiscal year (or period) only to such extent as is provided in appropriation Acts.

Passed the House of Representatives September 5, 1975.

Attest: W. PAT JENNINGS,

Clerk.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION,
Washington, D.C., July 22, 1975.

Hon. WARREN G. MAGNUSON,
Chairman, Committee on Commerce, U.S. Senate, Washington, D.C.

DEAR MR. CHAIRMAN: This is in further reply to your request for the comments of the National Aeronautics and Space Administration on the bills S. 1632 and H.R. 8800 "To authorize in the Energy Research and Development Administration a Federal program of research, development, and demonstration designed to promote electric vehicle technologies and to demonstrate the commercial feasibility of electric vehicles."

The bill would direct ERDA to conduct a specialized program for promoting the technologies and demonstrating the commercial feasibility of urban electric vehicles for individual and business use by establishing an organizational entity within ERDA known as the Electric Vehicle Research, Development and Demonstration Project. ERDA would have overall management of the project but would be authorized to enter into agreements with other federal agencies, including NASA, as is necessary or appropriate for the conduct of the project.

ERDA would have the specific responsibility for promoting basic research on electric vehicle batteries, controls, and motors; determining optimum overall vehicle design; conducting feasibility demonstrations; ascertaining consumer needs and desires; and ascertaining changes in road design, urban planning, maintenance facilities, utility rate structures and tax policies which would be needed to facilitate the manufacture and use of electric vehicles.

NASA has done extensive work in areas of technology relevant to electrical vehicle development. These areas include, for example, batteries, electric control systems, electric motors, materials, lightweight structures, etc. All of these technologies were employed in the development of the lunar roving vehicle, which had the characteristics of both a spacecraft and an electric vehicle. As an example of our current involvement in urban electric vehicle technology, NASA is funding a small demonstration of the application of nickel-zinc batteries in postal service vehicles. Also, ERDA and NASA have just recently signed a Memorandum of Understanding under which we hope to cooperate closely with ERDA in this and other areas of mutual interest.

Since ERDA would be the agency primarily responsible for the conduct of the project envisioned by S. 1632, NASA defers to ERDA for substantive comments on the desirability or the need for that bill.

The Office of Management and Budget has advised that, from the standpoint of the Administration's program, there is no objection to the submission of this report to the Congress.

Sincerely,

GERALD D. GRIFFIN,
Assistant Administrator for Legislative Affairs.

GENERAL COUNSEL OF THE DEPARTMENT OF COMMERCE,
Washington, D.C., September 9, 1975.

Hon. WARREN G. MAGNUSON,
Chairman, Committee on Commerce, U.S. Senate, Washington, D.C.

DEAR MR. CHAIRMAN: This letter is in response to your request for the views of this Department on S. 1632, a bill to authorize in the Energy Research and Development Administration a Federal program of research, development, and demonstration designed to promote electric vehicle technologies and to demonstrate the commercial feasibility of electric vehicles.

This bill proposes that the Administrator of the Energy Research and Development Administration establish as an organizational entity within that agency the Electric Vehicle Research, Development and Demonstration Project. The overall management of this project would be the responsibility of the Administrator who would promote basic research on all aspects of electric vehicles; determine optimum electric vehicle design; demonstrate through Government and private users the commercial feasibility of electric vehicles; and ascertain the long-term changes in road design, urban planning, traffic management, maintenance facilities, utility rate structures, and tax policies needed to facilitate the manufacture and use of electric vehicles.

The bill provides that appropriations totaling $1.2 million will fund the three year research and development project. The Administrator is allotted specific time periods in which to produce "significant numbers" of electric vehicles and to develop performance standards and criteria for private and commercial electric vehicles. The Administrator would also arrange for actual test use of electric vehicles in the fleets of Federal, state, and local governments and by various individuals and businesses. In addition, the Administrator would be charged with the responsibility of studying various incentives which might be used to encourage use of electric vehicles and to make certain assessments as to the results of electric vehicle use. Periodic reports on the overall activities, internal evaluations, and progress of the project would be submitted to Congress.

This Department, while supporting the fundamental concept that development of more desirable alternative forms of individual and commercial transportation should be an on-going process, opposes enactment of this bill in its present form.

The major premise of this bill is that direct Federal supervision of a major program of research and development will expedite the substitution of an electric vehicle for the conventional modes of individual and commercial transportation. While the Government can decidedly play an important role in exploring the feasibility of electric vehicles, it must be recognized that private industry already has substantial experience in this area and continues to exert great efforts in the development of practical electric vehicle transportation.

The development of a completely new vehicle for mass production is a task of monumental proportions requiring great sums of money and years of development. Considerable progress has been made by private industry in the overall development of electric vehicles, but an area of particular need for advancement is energy storage technology.

It would be inappropriate for the Government to assume a direct managerial or supervisory role in a massive electric vehicle development project such as is proposed in this bill. Rather, Government participation should be limited to funding of battery technology research and development. Furthermore, such funding should be on a selective basis; that is, an attempt should be made to avoid duplicating the efforts in battery technology development of both private industry and Federal instrumentalities such as the Postal Service, General Services Administration, and the Energy Research and Development Administration.

We have been advised by the Office of Management and Budget that there would be no objection to the submission of our report to the Congress from the standpoint of the Administration's program.

Sincerely,

B. Parrette,
Deputy General Counsel.

Comptroller General of the United States,
Washington, D.C., September 18, 1975.

Hon. Warren G. Magnuson,
Chairman, Committee on Commerce,
U.S. Senate, Washington, D.C.

Dear Mr. Chairman: Reference is made to your letter dated June 2, 1975, requesting our comments concerning S. 1632, 94th Congress, a bill which, if enacted, would be cited as the "Electric Vehicle Research, Development, and Demonstration Act of 1975." The stated purpose of the bill is to authorize in the Energy Research and Development Administration (ERDA) a Federal program of research, development and demonstration designed to promote electric vehicle technologies and demonstrate the commercial possibility of electric vehicles.

We note that in enacting the Energy Reorganization Act of 1974 (Act), approved October 11, 1974, Pub. L. No. 93-438, 88 Stat. 1233, the Congress declared its purpose to be:

"Sec. 2. (a) * * * the general welfare and the common defense and security require effective action to develop, and increase the efficiency and reliability of use of, *all energy sources to meet the needs of present and future generations*, to increase the productivity of the national economy and strengthen its position in regard to international trade, to make the Nation self-sufficient in energy, to advance the goals of restoring, protecting, and enhancing environmental quality, and to assure public health and safety.

"(b) The Congress finds that, to best achieve these objectives, improve Government operations, *and assure the coordinated and effective development of all energy sources*, it is necessary to establish an Energy Research and Development Administration to bring together and direct Federal activities relating to research and development on the various sources of energy, to increase the efficiency and reliability in the use of energy, and to carry out the performance of other functions, including but not limited to the Atomic Energy Commission's military and production activities and its general basic research activities. In establishing an Energy Research and Development Administration to achieve these objectives, *the Congress intends that all possible sources of energy be developed consistent with warranted priorities*." (Italic, supplied.)

It is clear, therefore, that in establishing ERDA the Congress intended that it possess broad authority to address the Nation's energy problems and, further, that it possess the flexibility to weigh all research and development alternatives to assure coordinated and effective development of all energy sources consistent with warranted priorities. While the bill would vest responsibility for developing electric vehicle technology in ERDA, it would also limit the flexibility of ERDA to make determinations regarding research and development after carefully considering and weighing all the alternatives. It is the belief of this Office that the enactment of specific legislation which favors selected energy research and development programs serves only to reduce the range of options available to ERDA in making its research and development determinations.

Section 5(a) of the bill directs the Administrator of ERDA to establish an organizational entity within ERDA to be known as the Electric Vehicle Research, Development, and Demonstration Project. With the exception of certain upper echelon positions in ERDA prescribed by section 102 of the Act and the transfer of certain entities established by law in the Atomic Energy Commission provided for by section 104(d) of the Act, section 105(d) of the Energy Reorganization Act of 1974 grants the ERDA Administrator the authority to organize ERDA as he may deem necessary or appropriate. The Committee may wish to reconsider the advisability of impinging on this flexibility.

We note that section 5(b) of the bill would authorize the Administrator of ERDA to enter into such arrangements and agreements with various Federal offices and agencies as he may deem necessary or appropriate for the conduct by them of parts or aspects of the project which are within their particular competence. Section 104(i) of the Energy Reorganization Act of 1974 already directs the Administrator of ERDA to utilize to the fullest extent he may determine advisable with their consent the technical and management capabilities of other executive agencies having facilities, personnel, or other resources which can assist or advantageously be expanded to assist in carrying out such responsibilities. Pursuant to this provision, cooperation with NASA has already been accomplished by an agreement signed June 23, 1975, whereby NASA would assist ERDA in three broad areas, one of which is ground propulsion technology. Thus the Committee might wish to consider the deletion of section 5(b) of the bill as being unnecessary.

Section 7(b) of the bill would require that the Administrator develop performance standards and criteria which are suitable for the needs of urban private passenger vehicles and urban commercial vehicles within 180 days of enactment of the bill. Based upon the criteria and standards established, the Administrator would be required by section 7(a) of the bill to enter into contracts (1) for the production within 18 months of the bill's enactment of significant numbers (defined as 5,000 or more by section 4(4) of the bill) of vehicles which have electric propulsion systems on conventional chassis, and (2) for the production within 3 years of the bill's enactment of significant numbers of vehicles which are specifically designed for electronic propulsion systems as the primary power source. The 180 day limitation placed upon the Administrator by section 7(b) may not allow sufficient time to develop criteria and standards which may have to be coordinated with other executive agencies, and to publish such standards and criteria for necessary public discussion. We also believe that there is insufficient time for the other elements of the demonstration program to be accomplished within the 18 months and 3 year's time constraints established by this bill.

Finally, section 12 of the bill would authorize appropriations in amounts not to exceed $40 million for each of the 3 fiscal years 1976, 1977 and 1978. Funds authorized for the first 2 years but not appropriated may be appropriated for any succeeding fiscal year through the third year. The bill authorizes these appro-

priations without fiscal year limitation. Appropriations for the regular operations of a department, other than for construction and other capital needs, have traditionally been authorized on an annual basis, and we call the Committee's attention to section 253 of the Legislative Reorganization Act of 1970 which provides that each standing Committee in its consideration of bills shall endeavor to insure that all continuing programs and activities of the Federal Government are carried on with annual appropriations to the extent consistent with the objectives of those programs and activities.

Sincerely yours,

ROBERT F. KELLER,
Deputy Comptroller General,
of the United States.

U.S. POSTAL SERVICE,
LAW DEPARTMENT,
Washington, D.C., October 2, 1975.

Hon. WARREN G. MAGNUSON,
Committee on Commerce, U.S. Senate,
Washington, D.C.

DEAR MR. CHAIRMAN: This responds to your request for comments on H.R. 8800 and S. 1632, proposals relating to the development of new energy-saving vehicles.

S. Con. Res. 37 would encourage the Secretary of Transportation to establish a program of research to develop a more energy-efficient passenger automobile. While the Postal Service does use some passenger automobiles, they comprise a very small portion of the postal vehicle fleet. Of course, we would appreciate the opportunity to take advantage, to the extent of our needs for passenger cars, of new technology that would improve energy- and pollution-saving performance in an economically feasible manner. However, since Postal Service activity in the area of passenger car technology is minimal, we defer to the views of the Department of Transportation with respect to the need for the proposed resolution.

S. 1632 and H.R. 8800 would each authorize a Federal program of research, development and demonstration designed to promote general electric vehicle technologies and to demonstrate the commercial feasibility of electric vehicles. This program would be coordinated in the Energy Research and Development Administration (ERDA).

Section 8 would require the Postal Service and other agencies to introduce electric vehicles into their fleets as soon as possible. The competitive position of electric models for procurement purposes would be required to reflect life-cycle costing and emission performance. Where the Postal Service or any other Federal agency determined that electric vehicles would be practical from a general performance standpoint but would not be economically competitive with conventional vehicles, the ERDA Administrator would be authorized to pay the increment necessary to make the electric vehicles fully competitive, as part of a demonstration program provided for under section 7.

In recent years, the Postal Service has undertaken a number of experimental projects to develop energy-saving alternatives to conventional vehicles used for mail delivery. In April of 1974, we entered into a procurement through the General Services Administration for a total of 352 light delivery electric vehicles, produced by the AM General Corporation. These vehicles generally are counterparts of our ¼-ton light delivery internal-combustion jeep-type vehicles, which presently cost about $3,100 each, compared to the approximately $5,700 paid for each of the electric vehicles. We are now about to begin field operational testing, primarily in the southern California area, as the first deliveries under the contract become available.

Provided that the first 352 vehicles are successful from a cost and performance standpoint, we have additional plans to procure perhaps 1000 more electric vehicles late in fiscal year 1976. In all, we presently have approximately 69,100 ¼-ton light delivery vehicles in our fleet. We are in the midst of a long term procurement contract with AM General for conventional gasoline-fueled vehicles. That contract provides for options to purchase additional vehicles should the requirement exist. Late in Fiscal Year 1977, we will be facing another large scale procurement. At that time we will have sufficient cost data to determine how much of that purchase should be in electric vehicles. We have sufficient routes .table to electric vehicle use to enable us to employ more of such vehicles should ir use prove economically feasible.

Sufficient supportable comparative data with respect to life-cycle costs were not available to enable us to take those considerations into account in procuring the electric vehicles we are now receiving. However, we are hopeful that our experience with these new vehicles within six or seven months after they are placed into operation will permit reasonable projections of life-cycle costs at the time of our next planned electric vehicle procurement in late FY 1976. Such estimates should enable us to have a better view of the comparative total economic costs of electric and conventional vehicles than is provided by comparing their initial purchase prices. We are confident that electric vehicles will be shown to permit significant energy savings in certain applications such as postal delivery routes requiring frequent stops and we believe that they are potentially good economic investments when used under appropriate conditions.

Since the Postal Service has decided that our particular needs justify an experimental program of electric vehicle purchases financed entirely from postal funds, it would appear that the need for legislation establishing a compulsory government program financed in part through ERDA subsidies should depend primarily on the need for such a program covering other agencies and the private sector. Accordingly, we defer, with respect to the merits of this particular legislative proposal, to the views of other interested agencies. We will be pleased in any case to work with ERDA in connection with our electric vehicle program and would welcome ERDA funding, if it is decided that it should be made available, to the extent that additional electric vehicles that would meet our needs cannot yet be shown to be economically competitive with conventional vehicles.

In the next few months we will have significant cost and operational data developed regarding electric vehicles and we, of course, would be pleased to make our data available to ERDA or any other interested agency.

Sincerely,

W. Allen Sanders,
Assistant General Counsel,
Legislative Division.

U.S. Environmental Protection Agency,
Office of the Administrator,
Washington, D.C., October 20, 1975.

Hon. Frank E. Moss,
Chairman, Subcommittee for Consumers, Committee on Commerce, U.S. Senate, Washington, D.C.

Dear Senator Moss: This is in response to your letter of September 19, 1975, concerning S. 1632 and H.R. 8800, both entitled "Electric Vehicle Research, Development, and Demonstration Act of 1975."

The underlying purpose of both of these bills is to demonstrate the commercial feasibility of electric vehicles for individual and business use, and to encourage research and development in new technologies for electric vehicles with wider application. Authority under both bills would be vested in the Energy Research and Development Administration (ERDA).

Under both bills, the Administrator of ERDA would be required to initiate and provide for the conduct of research and development in areas related to electric vehicles, including (1) energy storage technology, including batteries and their potential for convenient recharging; (2) vehicle control systems and overall design for energy conservation, including the use of regenerative braking; (3) urban design and traffic management for optimum transportation-related energy use and minimum transportation-related degradation of the environment; and (4) vehicle design for maximum practical lifetime, ease of repair, and interchangeability and replaceability of parts.

Both bills contain provisions for the demonstration of the feasibility of electric vehicles and for standards of performance.

Under H.R. 8800 the Administrator of ERDA would be required to establish a three-stage program for the purchase of electric vehicles:

(1) Within one year contracts would be entered into for a "reasonable number" of electric vehicles to demonstrate the current state-of-the-art;

(2) Within 15 months contracts would be entered into for 2500 vehicles meeting the initial specified performance standards; and

(3) Within 42 months contracts would be entered into for 5,000 vehicles meeting improved performance standards.

Under S. 1632, a two-step demonstration program is provided:

(1) Within 18 months contracts would be entered into for "significant numbers" (defined as 5,000 or more) of vehicles with electric propulsion system on conventional chassis; and

(2) Within three years contracts would be executed for "significant numbers" of vehicles which are specifically designed for electric propulsion as the primary source.

This bill also provides for performance standards for the above two types of vehicles.

Identical provisions in both bills provide for: (a) the introduction of such electrical vehicles into the vehicle fleets of government agencies at all levels and individual and business use, (b) the evaluation of performance and consumer reaction, (c) model training projects on maintenance procedures, and (d) dissemination of data on safety and operating characteristics.

Similar provisions in the bills would require the Administrator of ERDA to (1) conduct a study and report to Congress within six months on the existence of any tax, regulatory, traffic, urban design and other institutional factors which might bias transportation systems toward vehicles of particular characteristics (H.R. 8800 expands this to include a study of rural effects); (2) conduct a continuing assessment of long-range materials demand and potential pollution effects of electrification of urban traffic; and (3) have studies made on incentives to promote broader utilization and consumer acceptance of electric vehicle technologies. In addition, under H.R. 8800 within 240 days the Secretary of Transportation would be required to conduct a study on the applicability of safety standards.

Both bills contain provisions for the encouragement and protection for the participation of small businesses, and for semi-annual reports to Congress.

Three new elements are introduced in H.R. 8800:

(1) *Hybrid vehicles.*—Hybrid vehicles are included throughout the bill in addition to vehicles powered solely by electric engines;

(2) *Rural application.*—The potential of electric vehicles for use in agriculture and in rural areas is added; and

(3) *Loan guarantees.*—To encourage participation by small business, loan guarantees would be available for purposes and under conditions set forth in the bill.

Authorizations for appropriations total $120 million for a three-year period under S. 1632 and $160 million for a five-year period under H.R. 8800.

The questions enclosed with your letter of September 19 related to specific aspects of these bills. Inasmuch as ERDA, the Department of Transportation, and the Department of the Treasury have the primary expertise in the areas of energy development, transportation, and finance, we defer to these agencies with regard to your specific questions. We do, however, have comments on a number of issues concerning this legislation.

We endorse the goal of developing energy-efficient and non-polluting means of transportation. However, we do not believe that this will be accomplished through the enactment of either S. 1632 or H.R. 8800 at this time.

We agree with those proponents of electric vehicles who are concerned that "premature" demonstration of such vehicles may lead to a negative public reception. For instance, if the currently available vehicles fall short of public expectations for urban and rural use, the long-run potential of this mode of transportation may never be realized.

Knowledge gained from our authorities under the Clean Air Act indicates that the major limiting factor on the use of electric vehicles is the current inadequacy of storage batteries. We, therefore, believe that the primary Federal research effort should focus on the development of a battery with sufficiently high power and energy density to provide adequate vehicle range and road performance. The development of motors, chassis. controls, and other components of the vehicle could, and should, be left to industry. As you know, the AAPS program (research, development, and demonstration of alternative automotive power systems) under the Clean Air Act was transferred to ERDA in January of this year.

Although there is some disagreement among independent analysts and electric car enthusiasts, EPA has concluded that electric vehicles constructed with existing technology cannot provide the types of transportation services which privately-owned automobiles are excepted to perform in an energy efficient manner. An exception to this would be applications such as milk delivery trucks, which encounter numerous stops and starts and relatively extended periods of engine idling.

Although the wide-spread use of electric vehicles would reduce the emissions of HC, CO, and NO_x, the generation of the electricity to power these cars could increase other emissions. At this point, it is premature to evaluate the net effects of such a program on the national ambient air quality—the tradeoffs are unknown. The nature of the pollution resulting from large-scale electric vehicle usage would also depend upon whether fossil or nuclear powerplants were used and where they would be sited.

Since improved batteries are essential before an electric vehicle can be a viable substitute for the conventional internal combustion vehicle in urban areas, we believe that research priority should be directed toward that goal. Related problems can only be addressed realistically if that goal is achieved.

For these reasons, the Environmental Protection Agency recommends that a more desirable approach would be for ERDA to continue with the research program on an improved battery and to defer any decisions relating to demonstration and procurement programs until the battery technology is better developed.

The Office of Management and Budget has advised that there is no objection to the submission of this report from the standpoint of the Administration's program.

Sincerely yours,

JOHN QUARLES,
Deputy.

DEPARTMENT OF THE ARMY,
Washington, D.C., November 10, 1975.

Hon. WARREN G. MAGNUSON,
Chairman, Committee on Commerce, U.S. Senate, Washington, D.C.

DEAR MR. CHAIRMAN: Reference is made to your request to the Secretary of Defense for the views of the Department of Defense on S. 1632, 94th Congress, a bill "To authorize in the Energy Research and Development Administration a Federal program of research, development, and demonstration designed to promote electric vehicle technologies and to demonstrate the commercial feasibility of electric vehicles." The Department of the Army has been assigned responsibility for expressing the views of the Department of Defense on this bill.

The title of the bill states its purpose.

This bill would provide emphasis in solving those technological problems associated with electric-powered vehicles and will encourage industry to pursue its application. Inasmuch as enactment of the bill would not significantly affect the operations of the Department of Defense, the Department of the Army on behalf of the Department of Defense defers to the views of the Energy Research and Development Administration as the agency having primary interest in this matter.

The enactment of this bill will cause no apparent increase in budgetary requirements of the Department of Defense.

This report has been coordinated with the Department of Defense in accordance with procedures prescribed by the Secretary of Defense.

The Office of Management and Budget advises that, from the standpoint of the Administration's program, there is no objection to the presentation of this report for the consideration of the Committee.

Sincerely,

MARTIN R. HOFFMANN,
Secretary of the Army.

OFFICE OF THE SECRETARY OF TRANSPORTATION,
GENERAL COUNSEL,
Washington, D.C., October 7, 1975.

Hon. WARREN G. MAGNUSON,
Chairman, Committee on Commerce,
U.S. Senate, Washington, D.C.

DEAR MR. CHAIRMAN: This letter is in response to your request for the views of this Department on H.R. 8800, an act: "To authorize in the Energy Research and Development Administration a Federal program of research, development, and demonstration designed to promote electric vehicle technologies and to demonstrate the commercial feasibility of electric vehicles."

Section 2 details the economic and environmental findings of Congress and suggests a Federal role in promoting development of electric and hybrid vehicles. Section 3 states a policy of encouraging R&D on electric and hybrid vehicles with the goal of introducing them into the fleet, and Section 4 defines key terms used in the bill. Sections 5 and 6 delegate project management to ERDA and define the responsibilities of management and objectives of the project. Section 7 establishes a timetable for developing performance standards and criteria and for production of electric and hybrid vehicles. Section 8 authorizes the introduction of electric and hybrid vehicles into the Federal Government fleets. Section 9 authorizes the Administrator to conduct research on incentives to promote use of electric vehicles and to assess long-range material demand and pollution effects which may be caused by electrification of urban traffic, and on the applicability of safety regulations to such vehicles. Section 10 requires efforts to ensure that small business concerns and individuals have adequate opportunity to participate in the program. Section 11 authorizes loan guarantees to assist the commercial development of electric and hybrid vehicles and sets limits on the total amount available to a single qualified borrower. Section 12 outlines the contents of the semi-annual reports to Congress. Section 13 authorizes appropriations in the total amount of $160,000,000 for the period through fiscal year 1980.

The Secretary's recent statement of national transportation policy noted our intention to preserve and maximize the unique contributions of the automobile while striving to increase its energy efficiency, economic and socially responsible use, and safety. The more intelligent and socially responsible use of automobiles is a matter of urgent and continuing concern.

The Department has been and is involved in a number of activities that are relevant to issues raised by the act. For several years the Department has conducted studies and sponsored research related to the energy usage of automotive vehicles. Several of these studies have been evaluations of the present and potential capabilities of automotive power plants, including electric propulsion systems. The Department's automotive energy efficiency program, while assessing the improvements in fuel economy that manufacturers may make in their production vehicles over the coming years, has also supported evaluations of high performance batteries and of hybrid engines for cars. The National Highway Traffic Safety Administration (NHTSA) is supporting development of automobiles with substantial improvements in safety performance consistent with good emissions control and good fuel economy. The Department last year conducted with the Environmental Protection Agency a Congressionally mandated study of potential improvements in motor vehicle fuel economy. This year it is leading the Interagency Task Force on Motor Vehicle Goals Beyond 1980. In addition, the Secretary is a member of the Low Emission Vehicle Certification Board (established by Sec. 212 of the Clean Air Act), which has considered electric vehicles exclusively.

Based on this specific experience concerning electric vehicles and our experience concerning automotive vehicles and their use, we have several observations.

First, electric vehicles available today are not competitive with conventional automobiles for reasons tied to the characteristics of available batteries. The low energy and power densities of lead-acid batteries put rather severe limitations on the range of electric vehicles. If electric vehicles are ever to be competitive with heat-engine powered cars, it will be necessary to develop high performance batteries. Other special requirements of electric vehicles are relatively minor.

Second, vehicles which are to be used by a large segment of the motoring public must be evaluated in terms of the real requirements the market imposes on those vehicles, as well as the requirements imposed by Federal regulatory agencies. Electric vehicles designed for a segment of the automobile market should be compared with cars designed for that same market using the technology of the spark-ignition engine or using technology that would be available in the same time as the advanced battery.

Third, the potential benefits of electric vehicles appear problematical after close objective examination. For example, the overall energy efficiency (miles per energy unit) of electric vehicles on a typical urban driving cycle is somewhat uncertain but appears to be less than the energy efficiency of a car with spark-ignition engine designed to the same performance levels. Also, the environmental benefits are a tradeoff between less hydrocarbons, carbon monoxide, and oxides

of nitrogen produced at street level and more oxides of nitrogen and sulfur produced by fossil fueled stationary power plants, or, if nuclear power plants are used, these would be other environmental effects.

Fourth, if large numbers of electric vehicles are to enter the fleet of cars on the road, they should offer the same minimum degree of safety performance as required of conventional vehicles produced in the same year. The occupants of electric vehicles would be exposed to much the same hazards as occupants of other cars and deserve the same degree of protection. In addition, safety hazards associated with the battery must be given adequate consideration to hold the risk to the public to levels consistent with normal use of automobiles.

Fifth, substantial changes would be required in the infrastructure of sales, maintenance, fuel supply, etc., which support automobile use if electric vehicles should come into large scale use.

With respect to H.R. 8800, we support the concept that ERDA should support research and development of batteries for electric vehicles. It is appropriate for ERDA to support the R&D through the exploratory development and advanced development phases. It would not be appropriate for ERDA to develop advanced batteries to the point of commercial production. Commercial battery producers in private industry should retain that responsibility.

It is our view that the demonstration of electric vehicles by the Federal Government is premature by many years considering the maturity of electric vehicle technology. Moreover, it is not at all clear that the public would benefit enough from the use of electric vehicles to warrant their demonstration. The effect of the demonstration would be to stimulate the electric vehicle market, in effect, through an indirect subsidy to the producers of electric vehicles. Electric vehicles are already being produced for a small market and are being evaluated by a variety of users. If people are sufficiently convinced of the value of electric vehicles for their purposes, they can obtain the vehicles from suppliers. There does not appear to be good justification at this time for Federal intervention of this type in the electric vehicle market.

It also appears that the timetable set forth in the act for purchase of electric vehicles and for the development of criteria may be too short to be carried out with effective results.

For these reasons we believe the demonstration aspects of the act should not be supported.

The Office of Management and Budget has advised that there is no objection from the standpoint of the Administration's program to the submission of this report for the consideration of the Committee.

Sincerely,

JOHN HART ELY.

GENERAL COUNSEL
OF THE DEPARTMENT OF COMMERCE,
Washington, D.C., October 9, 1975.

Hon. WARREN G. MAGNUSON,
Chairman, Committee on Commerce,
U.S. Senate, Washington, D.C.

DEAR MR. CHAIRMAN: This letter is in response to your request for the views of this Department on H.R. 8800, an Act to authorize in the Energy Research and Development Administration a Federal program of research, development, and demonstration designed to promote electric vehicle technologies and to demonstrate the commercial feasibility of electric vehicles.

This Act proposes that the Administrator of the Energy Research and Development Administration establish as an organizational entity within that agency the Electric Vehicle Research, Development and Demonstration Project. The overall management of this project would be the responsibility of the Administrator who would promote basic research on all aspects of electric and hybrid vehicles; determine optimum electric and hybrid vehicle design; demonstrate through Government and private users the commercial feasibility of electric and hybrid vehicles; and ascertain the long-term changes in road design, urban planning, traffic management, maintenance facilities, utility rate structures, and tax policies needed to facilitate the manufacture and use of electric and hybrid vehicles.

The Act provides that appropriations totaling $1.6 million will fund the five-year research and development project. The Administrator is allotted three

specific time periods in which to produce first a reasonable number of electric vehicles for tests and demonstration of current state-of-the-art; then produce at least 2,500 electric vehicles with available components and design; and finally, produce at least 5,000 electric and hybrid vehicles with advanced components and design. The Administrator is given one year to develop initial performance standards and criteria for private and commercial electric vehicles and is to revise these performance standards and criteria periodically as the state-of-the-art improves. The Administrator would also arrange for actual test use of electric and hybrid vehicles in the fleets of Federal, state, and local governments and by various individuals and businesses including farms. In addition, the Aministrator would be charged with the responsibility of studying various incentives which might be used to encourage use of electric and hybrid vehicles and to make certain assessments as to the results of their use. The Administrator is authorized to guarantee lenders against loss of principal or interest on loans made to electric vehicle developers and manufacturers. Reports are to be submitted semiannually to Congress on all activities being undertaken and carried out pursuant to this Act.

This Department, while supporting the fundamental concept that development of more desirable alternative forms of individual and commercial transportation should be an on-going process, opposes enactment of this legislation in its present form.

The major premise of this Act is that direct Federal supervision of a major program of research and development will expedite the substitution of an electric vehicle for the conventional modes of individual and commercial transportation. While the Government can decidedly play an important role in exploring the feasibility of electric vehicles, it must be recognized that private industry already has substantial experience in this area and continues to show great interest in the development of practical electric vehicle transportation.

The development of a completely new vehicle for mass production is a task of monumental proportions requiring great sums of money and years of development. Considerable progress has been made by private industry in the overall development of electric vehicles, but an area of particular need for advancement is energy storage technology.

It would be inappropriate for the Government to assume a direct managerial or supervisory role in a massive electric vehicle development project such as is proposed in this Act. Rather, Government participation should be limited to funding of battery technology research and development. Furthermore, such funding should be on a selective basis; that is, an attempt should be made to avoid duplicating the efforts in battery technology development of both private industry and Federal instrumentalities such as the Postal Service, General Services Administration, and the Energy Research and Development Administration.

We have been advised by the Office of Management and Budget that there would be no objection to the submission of our report to the Congress from the standpoint of the Administration's program.

Sincerely,

B. Parrette,
Deputy General Counsel.

Department of State,
Washington, D.C., October 20, 1975.

Hon. Warren G. Magnuson,
Chairman, Committee on Commerce,
U.S. Senate, Washington, D.C.

Dear Mr. Chairman: Secretary Kissinger has asked me to reply to your letter of September 16 requesting the State Department's comments on H.R. 8800, an act "to authorize the Energy Research and Development Administration a Federal program of research, development, and demonstration designed to promote electric vehicle technologies and to demonstrate the commercial feasibility of electric vehicles."

The issue addressed in H.R. 8800 is of primary concern to other agencies. The Department of State defers to their views.

The Office of Management and Budget advises that from the standpoint of the Administration's program there is no objection to the submission of this report.

Sincerely yours,

Robert J. McCloskey,
Assistant Secretary for
Congressional Relations.

DEPARTMENT OF AGRICULTURE,
Office of the Secretary,
Washington, D.C., November 13, 1975.

Hon. WARREN G. MAGNUSON,
Chairman, Committee on Commerce,
U.S. Senate, Washington, D.C.

DEAR MR. CHAIRMAN: This is in reply to your request of September 16, 1975 for a report on H.R. 8800, the "Electric Vehicle Research, Development, and Demonstration Act of 1975."

This Department recommends the bill not be enacted.

The bill would authorize in the Energy Research and Development Administration a Federal program of research, development, and demonstration designed to promote electric vehicle technologies and to demonstrate the commercial feasibility of electric vehicles. We understand that the ERDA authorization includes research, development, and demonstration of electric vehicles. Therefore, this bill appears unnecessary.

The Office of Management and Budget advises that there is no objection to the presentation of this report from the standpoint of the Administration's program.

Sincerely,

RICHARD A. ASHWORTH,
Deputy Under Secretary.

ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION,
Washington, D.C., November 18, 1975.

Hon. WARREN G. MAGNUSON,
Chairman, Committee on Commerce,
U.S. Senate, Washington, D.C.

DEAR MR. CHAIRMAN: In response to your request for comments on S. 1632 and H.R. 8800, 94th Congress, we are pleased to advise that such comments were provided in the testimony of Mr. Austin Heller, Assistant Administrator for Conservation, before the Subcommittee on Science, Technology and Commerce on October 10, 1975. The ERDA comments on Senate Concurrent Resolution 37, 94th Congress, will be supplied separately.

Sincerely,

R. TENNEY JOHNSON,
General Counsel.

THE GENERAL COUNSEL
OF HOUSING AND URBAN DEVELOPMENT,
Washington, D.C., November 24, 1975.

Hon. WARREN G. MAGNUSON,
Chairman, Committee on Commerce,
U.S. Senate, Washington, D.C.

DEAR MR. CHAIRMAN: This is in further reply to your letter requesting the views of this Department on H.R. 8800, the proposed "Electric Vehicle Research, Development and Demonstration Act of 1975."

H.R. 8800 would establish in the Energy Research and Development Administration (ERDA) a project for research and development in areas related to electric vehicles, and for demonstrations of the feasibility of urban passenger and commercial electric and hybrid vehicles. It would also require the introduction of electric and hybrid vehicles into the fleets of Federal agencies as soon as possible. In addition, H.R. 8800 would direct ERDA to take specified steps to assure participation of small businesses in the project, and would authorize ERDA to guarantee loans made to small businesses for research and development, construction of capital equipment, and initial operating expenses associated with the development and production of electric vehicles and components.

The Department of Housing and Urban Development defers to ERDA, as the agency which would be responsible for implementing H.R. 8800, with respect to whether its provisions are desirable or necessary. With respect to the provision regarding introduction of electric and hybrid vehicles into Federal agency fleets, we would also defer to the General Services Administration, the Postal Service, and the Department of Defense.

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The Office of Management and Budget has advised that there is no objection to the presentation of this report from the standpoint of the Administration's program.

Sincerely,

DOUGLAS M. PARKER.
ROBERT R. ELLIOTT.

UNITED STATES OF AMERICA,
GENERAL SERVICES ADMINISTRATION,
Washington, D.C., February 25, 1976.

Hon. WARREN G. MAGNUSON,
Chairman, Committee on Commerce, U.S. Senate, Washington, D.C.

DEAR MR. CHAIRMAN: Your letter of September 16, 1975, requested the views of the General Services Administration on H.R. 8800, a bill "To authorize in the Energy Research and Development Administration a Federal program of research, development, and demonstration designed to promote electric vehicle technologies and to demonstrate the commercial feasibility of electric vehicles."

Section 7(c) of the proposed bill would require that the Administrator of the Energy Research and Development Administration make arrangements for the introduction of newly developed electric vehicles into Federal fleet for demonstration purposes. This provision would probably present no significant problems, but the General Services Administration defers to the Energy Research and Development Administration as to whether such a demonstration program would be useful at this time.

However, section 8(a) appears to speak in terms of substantial competitive procurement for use by Federal agencies, rather than in terms of testing and demonstration. From a procurement standpoint this section is inadequate for effective implementation. For example, it requires that in connection with the procurement of such vehicles "life cycle costing . . . shall be fully taken into account." It would be extremely difficult to determine just what the life cycle cost for a new type of vehicle would be. With no prior experience to use as a basis for estimates, one would simply have to guess at factors such as maintenance costs. The section also requires that "the beneficial emission characteristics of electric vehicles shall be fully taken into account." Yet the section does not clearly indicate what is meant by this provision, nor does it place a dollar value on "beneficial emission characteristics" for procurement purposes.

The section is also confusing inasmuch as it authorizes the Energy Research and Development Administration to pay the difference between conventional vehicles and the new electric vehicles. This provision implies that we are to negotiate contracts for the new vehicles. but the legal authority for such negotiation remains unclear.

Therefore, while we defer to ERDA on the overall need for H.R. 8800, we would recommend that the above problems be resolved before giving further consideration to the bill.

The Office of Management and Budget has advised that, from the standpoint of the Administration's program, there is no objection to the submission of this report to your Committee.

Sincerely,

(Signed) KENNETH M. DUBERSTEIN,
Director of Congressional Affairs.

Senator MOSS. We are fortunate today to have as our lead-off witness, Representative Mike McCormack of the State of Washington, who is author of H.R. 8800 and was the leader in securing its passage in the House. Representative McCormack is chairman of the Science Subcommittee of the Committee on Science and Technology. I know of no more knowledgeable person in this field than Mike McCormack. He is the one authentic real life scientist that we have in the Congress of

the United States. For that reason we turn to him very frequently, and we are certainly pleased that you are here this morning, Mike.

You have a prepared statement, which I am glad to place in the record in full, and you may have what leeway you need to tell us what you think we ought to hear and have in our record about the bills before us.

You are particularly knowledgeable about the House bill, and I would like to have you talk about that. You may proceed as you care to.

STATEMENT OF HON. MIKE McCORMACK, U.S. REPRESENTATIVE FROM WASHINGTON

Mr. McCORMACK. Thank you. I want to congratulate you on your leadership and all the other science-related programs you have been working on. I want to say I am very proud to have you as cosponsor of the electric vehicle research, development, and demonstration bill. I want to express my appreciation to you for inviting me here to testify today and to express my support for this program.

As you know, I was the original sponsor of this legislation in the House of Representatives, because I was convinced of the need to accelerate the development and demonstration of electric vehicle technology, so the people of America could soon have a viable option for their personal transportation, which is both energy conserving and not dependent on imported oil.

As we held our hearings on the House side, Mr. Chairman, one of the things that became most obvious was the genuine enthusiasm that developed among the committee members. Though they entered this whole matter rather cautiously, they came out in unanimous support of the legislation and enthusiastic in moving it forward as rapidly as possible.

I would like next to talk about a couple of the underlying facets of this bill. As you have said, Mr. Chairman, we use more petroleum for transportation than anything else. About 40 percent of our petroleum today is imported. It seems likely that we are going to run out of petroleum by the end of this century.

The ERDA national energy plan makes it clear we are headed toward an energy economy that will be heavily dependent upon electricity, generated by coal and nuclear fission during this century, late in the century, perhaps, with support from solar and geothermal energy and in the next century from nuclear fusion.

But what we are doing is taking a positive step to help replace the use of petroleum, either domestic or imported, by electricity produced from domestic sources. At the same time we are doing something else that is terribly important: that is to produce a transportation system for this country which not only conserves energy and is cheaper than the present system, but which retains the all-important characteristic of individual freedom of movement for the individual commuter. This is so terribly important, because mass transit, valuable as it is, confines the commuter to a fixed course. It deprives him of his liberty. The electric vehicle replaces the internal combustion engine, saves fuel and still retains the freedom individual Americans regard as being so important.

I suppose if we had had no energy crisis or if we had not become sensitive to pollution problems, the internal combustion engine would have remained unchallenged. Now, however, we are faced with the recent embargo, the high price on oil and the fact we are running out, plus the recognition that automobiles are the major source of pollution in our cities.

Of all the alternatives, electric vehicles appear to be the most promising. When considering what is and what is not being done with respect to the energy crisis, and what can and cannot be done, and what will have a significant impact in relieving the energy problems, we see that some programs have much greater value than others, because they will have a significant impact in the near future. As we on the Science and Technology Committee have analyzed the energy crisis and tried to provide solutions, we tried to pick pressure points for a small change in technology that is socially and economically and environmentally attractive to reduce the consumption of oil. We sought to have pressure points where demand for critical materials and fuels, petroleum today or gas in the near future, can be reduced specifically as compared with reducing energy consumption in general.

Switching to electric cars is such a program, particularly for second cars, as 40 percent of all the cars in America today are second cars. I hope the context of this bill can be kept in that particular light. We are talking primarily about second cars and specialized delivery vans for the immediate future. Electric cars will serve these purposes today.

More than 50 percent of all the trips, all the driving in this country, is 5 miles or less. A recent EPA study showed that 98 percent of all the driving of second cars in Los Angeles could be met by electric vehicles with a single battery charge per day. And this same EPA report suggested that in the Los Angeles region 17 percent of all the cars could be electric by 1980.

If we talk about replacing second cars with electric cars, I think it is interesting to see what the impact would be. There are 110 million cars in this country today and 40 to 50 million of them are second cars. We buy about 11 million new cars per year. If we can get to 10 million electric cars, shall we say, in the 1990 period, then we would be saving a half million barrels of petroleum per day. That is 3 to 5 percent of our domestic production. There is nothing else I know of—all the solar and geothermal technologies put together will not accomplish as much. We would save more energy than we would produce with solar, if we put 10 percent of all our houses on solar heating and cooling. This is really one of three things that we can do immediately to have a profound effect, not just through consumer orientation, but by actually reducing the demand for petroleum and natural gas without seriously altering our lifestyles. One is the introduction of electric vehicles, and the other two are improved efficiency in gasoline-powered cars and added insulation to reduce energy consumption in our homes.

The other fact, of course, is that we would be actually strengthening our whole electric utility system by providing demands during the nighttime, thus tending to level the load of the electric utility system.

Still another factor is that electric cars are much cheaper for use, in the cities in particular. Not only does an electric car not use energy

when it is stopped, but we will soon have technology, that is already available, applied to electric vehicles for recovery of electric energy for regenerative uses. That is, we may use the braking energy when going down hill or stopping to recharge the battery. Today, with cars we already have available, we can drive for 40 miles at about 40 miles per hour for about 40 cents worth of electricity. That is 10 to 12 kilowatt hours, at 3 to 4 cents per kilowatt hour. So, even where electricity is very expensive, operating an electric car is from one-fifth to one-third as expensive as operating any car, no matter how cheap it is, with an internal combustion engine. Where electricity is cheapest, such as in the West or Northwest, it only costs about one-tenth as much to drive an electric car as an internal combustion engine.

Also, we dramatically reduce noise pollution and pollution from exhausts in our cities, and remove that to electric generating plants. For those plants that use coal, we are making progress in reducing pollution from them. Of course, if they are nuclear, there is no pollution at all.

Now, the bill itself, H.R. 8800, as it passed the House, establishes a 5-year $160 million program for research, development, and demonstration under the ERDA. There are several steps in the program. The first is to have ERDA buy several hundred electric cars right away, within a year after the bill is passed. First, they would experiment with these vehicles and establish performance and safety criteria, and then within 15 months after the bill becomes law, ERDA would order 2,500 vehicles, meeting their safety and performance criteria, for delivery within 27 months. These 2,500 vehicles would then be distributed across the country in a series of programs for individual owners and fleets—municipalities and so on—for field testing and for demonstration to the American people just what electric cars can do. All through the last 50 years we have thought about what electric cars cannot do. The whole outlook has been, what electric cars can't do. They can't rev-up like an internal combustion engine. They are no substitute for sex or masculinity, like a high-powered engine is. You have to start thinking in terms of what they can do. So the concept of the demonstration bill is to demonstrate that electric cars will get us from one place to the other. They can provide for most of our commuting. They can replace our second cars.

Following the 2,500-car program, the cars would be sold after a year in the field, sold on some sort of equitable basis and the money returned to the Treasury. Two years later, following the research and demonstration program, we would buy 5,000 additional cars and do the same thing with them. What we are doing here is getting over the chicken-egg situation we have.

Today we have all kinds of people in the country that want electric cars. I have a picture of myself here in one of these electric cars we had over in front of the Horseshoe one day. If I may digress just a moment and comment, we accidently intercepted the Vice President when we arrived there with this electric car, and there was a crowd. We totally stole the crowd from the Vice President. The Vice President was totally ignored.

Driving this and other similar electric cars around the Capitol grounds and around L'Enfant Plaza, I felt that I was in one of those

unreal worlds of television commercials where a guy drives a new car and comes up to a stop sign and, all of a sudden, people come from all directions—"What kind of car is that?" "Where did you get it?" "How much does it cost?" "Can I buy one?" Every time I came to a stop, I would be inundated by people, people who have their hands on it, holding on to the car, holding on to me, wanting to know where they could buy an electric car.

This is the response we were getting. We are trying to give people a chance to buy one of these cars. One of the problems we have is the need to have an industry out there to make them. This bill will not only provide a loan guarantee program to start the industry off, but will let that industry know that we are going to buy 2,500 cars and then later on another 5,000 cars. They can go ahead and set up their assembly lines and get to work in their normal procedure of building and selling cars, realizing that a couple of dozen different individual manufacturers across the country are going to be winning contracts to sell cars to the government for this demonstration program.

I think this is one of the things that makes it most important. There is another facet to this whole demonstration, too. We are all aware of the fact that consumer reports in October criticizes electric vehicles as being not safe for driving. Of course, it is a matter of perspective. I don't think the manufacturers of these new small electric cars expected them to be out on the freeways, any more than I did. But it is quite clear that we need to have an official agency of the Federal Government taking a look at the safety and performance characteristics of this car. And this is just exactly what ERDA would do.

Incidentally, there would be a considerable technology transfer not only into the program, but from it. We have all sorts of technologies today that are available that have not been used in electric cars yet. For instance, there are new electronic controls to dramatically increase the efficiency and performance of electric cars; they are now being used in some new cars in Japan, but they have not yet been significantly applied to electric cars in this country.

On the other hand, the battery technology that is certain to be stimulated by this program is going to be extremely valuable in other areas, such as wind and solar energy, for example. This is another reason why ERDA is the right agency to carry out this program.

Some people have wondered whether ERDA is the right agency. This is a research and development operation going in and coming out. As you know, the administration has organized ERDA so it will handle energy and transportation programs, including the electric car program. Public Law 93–438, the Nonnuclear Energy Research and Development Act, which we passed last year, specifically provided that ERDA would have Advance Transportation Power Systems and, in fact, this year the House has authorized $27.5 million for this program in fiscal year 1976. Our electric vehicle bill was, first of all I think, skeptically viewed, when I brought it up on the House floor. It was unanimously approved by the subcommittee and the committee, however, and we worked carefully with ERDA, albeit somewhat surreptitiously, because the Office of Management and Budget has been looking down on this program. So our work with

ERDA was off the record, but we understand that they believe they can operate the plan, as we have developed it.

When the bill came to the House floor, in spite of the fact that there was last minute criticism of it from the Office of Management and Budget, it was passed by a vote of 308 to 60. I think that is enormously strong support for a bill authorizing $160 million.

Mr. Chairman, we have had some criticism of the bill, because of that figure, that $160 million program. The Washington Post criticized the bill, for instance, because it authorized $160 million. I find myself at a loss to understand the Washington Post criticism, when it supported a nearly identical solar energy program on a nearly identical basis.

I would like to point out this figure is equivalent to just 55 hours of imported petroleum. At the rate we are importing petroleum today, the entire $160 million bill is equivalent to 55 hours.

In addition, the cost is only $10 million this fiscal year. The larger amounts come when we get out in the future, actually buying the 2,500 and 5,000 cars.

Finally, if we have 10 million cars on the road, as I mentioned, the savings would be half million barrels of oil per day. That is 1 percent of our entire energy. It is 5 percent of our domestic petroleum production, 3 percent of all of our domestic consumption, but it is $5 million a day savings—just by having 10 million electric cars on the road.

So I commend the bill to you with our wholehearted enthusiasm, and I hope the full committee and Senate will be moved to enact this legislation rapidly, so it will give the American people an opportunity to have this real alternative, which provides financial and economic savings, and the freedom they have always cherished.

Thank you, Mr. Chairman.

Senator Moss. Thank you very much, Mike.

That certainly is an excellent overview of your bill. Approximately how many companies are making an electric car?

Mr. McCormack. I would guess between one and two dozen, Mr. Chairman. The Electric Vehicle News (February 1975) has a list of these. I am sorry I can't give you an exact answer. We do have a list of manufacturers in the committee files. I think it is between one and two dozen manufacturers.

Senator Moss. So there is some experimentation going on now, but as I understand it the thrust of your bill is that this experimentation would be encouraged by letting electric vehicle producers know that they were going to have a market to compete for in the next 2 or 3 years?

Mr. McCormack. That is correct. Mr. Chairman, you recognize we have two electric vehicle manufacturers supplying cars today, selling them, in measurable numbers. The *Citicar* (Sebring-Vanguard, Inc.) and the Elcar (Elcar Corp.)

Now, this is a start in the right direction. Both of these cars, as you know, are minimal, light city cars. Very practical for their intended use. There are many people, however, who want something somewhat more advanced. They want a second or third generation vehicle that is more consistent in design and performance with the vehicles that we are more accustomed to, such as light American cars.

Even though there are a few manufacturers around, we need to give them stimulus and the impetus to get out and do the research and development to improve their design and performance and their acceptability to the American people.

Senator Moss. Wasn't that really the one factor that the Washington Post objected to in its editorial? They felt that this legislation was in effect focused on merchandising an existing product.

Mr. McCormack. I think they missed the point completely; they seemed to have the impression that the government would be in the business of buying and selling cars. This is a demonstration program. Just exactly as the solar energy heating and cooling demonstration is. It is taking an infant technology that has been known for a long time. What it needs are the sophisticated modernizing refinements required for competitive application today—the critical boost to get it off dead center. I find it very difficult to rationalize support for the Solar Energy Heating and Cooling Demonstration Act and not support for the electric vehicle research and development bill.

Senator Moss. It is a difference, really, of testing in the shop or the laboratory and getting out and really road testing under actual functioning conditions. That is the part that they seem to object to.

Mr. McCormack. Yes. Again, I said they miss the point completely. The investment the Federal Government would make, would be extremely small in comparison to the payoff. Not only will these vehicles be sold after being leased or used for demonstration programs (with much of the cost returned to the Treasury), but the stimulus the program would provide would be tremendous. The saving of getting an electric car program, even a modest one, underway—with a number of small independent free enterprise manufacturers in this country—is so great in terms of savings of petroleum and energy in general, and savings to individual commuters, automobile owners, that I find almost nothing else that will compare to it.

Senator Moss. Do you know what the approximate retail price is of these two types of electric vehicles, which you state are now being generally distributed?

Mr. McCormack. These vehicles, you will have more accurate testimony on it, but I believe they retail slightly below or near $3,000.

Senator Moss. So they would be competitive with small combustion engine automobiles?

Mr. McCormack. Yes. I suspect the version we will see, like this more classic-looking streamline vehicle here, would be somewhat more comparable to cars in the United States selling for $4,000 to $5,000.

Actually, we had demonstration vehicles that ran up to $13,000, that was their estimated sale price, with trailers and batteries and generators and that sort of thing. I think for the average small car you are talking about $4,000 to $5,000. You are also talking about a far cheaper operational cost, much lower maintenance and much safer vehicle, because it would not be traveling at such high speeds and, of course, you reduce pollution along with it. On almost every count, the electric vehicle is superior, for the things we really want, except for high power and high speed. Of course, with that high power goes the opportunity to build a stronger steel shell around the driver; we have to provide adequate safety in these vehicles.

Senator Moss. Well, I would like to discuss this issue with you for a long time. We have a long list of witnesses, however, so I must forego that. I appreciate your appearance. My colleague from New York may have some questions for you.

Senator Buckley. Thank you very much. I am sorry I didn't come in at the beginning of your testimony. I saw those gadgets parked in front of the Capitol also. I feel the development of electric cars would solve a lot of problems. Assuming that the electricity used to charge a battery is generated by utilities using oil, what is the net saving in petroleum?

Mr. McCormack. We have analyses that suggest that even with a utility using oil it is beneficial. Our testimony is that an electric vehicle is more efficient in total energy system. A detailed analysis appears in the record of our Hearings on the Electric Vehicle Research, Development, and Demonstration Act of 1975 (Appendix B, document ANL–8075). Of course, you recognize, Senator Buckley, that most of the energy is soon to be generated either by coal or nuclear energy. There the savings, particularly with nuclear, are vast.

Senator Buckley. I recognize that.

Secondly, you speak of a consensus that within 2 years of a big risk development program, you could develop economically appropriate batteries at an economically competitive price. Do you have any price tags on what this particular effort would cost?

Mr. McCormack. We are talking about batteries as we think of them today that will be selling for $50 to $60. So a rack of 10 to 12 batteries would be $500 to $700 and would last for 3 to 4 years with normal operation.

Senator Buckley. What kind of a research program would develop such a battery? What is the cost of the program we are talking about?

Mr. McCormack. I cannot speak directly to the cost of the program. We have authorized quite a large amount of money, many millions of dollars in this general program, under the ERDA bill.

I would like to refer to representatives of the battery companies who may be testifying before you, rather than taking a chance of making a mistake.

Senator Buckley. Would we be duplicating the work ERDA has already done or accelerating the work?

Mr. McCormack. Accelerating. This is a technology to improve. As you are, I am sure, well aware, the incentive for better batteries has been with us for a long time and yet the progress has been quite slow. There are fundamental thermodynamic, materials and chemical reasons for that. Making the improvement we would like to make in terms of battery performance is a tough job, and it requires a great deal of support, a great deal of money, above and beyond what battery companies have normally been accustomed to put into it.

Senator Buckley. Yet you are confident that a 2-year test program could make the necessary breakthrough?

Mr. McCormack. This is the testimony that has come to us from several different battery manufacturers and research organizations. I can only take their word. I can say, however, that we can operate a program on the present batteries. If you buy the top of the line batteries, if you like, from Sears, Roebuck or J. C. Penney, they will

operate a vehicle as we described it, 40 miles for 40 cents a day at about 40 miles per hour. We hope to get substantially better performance.

Senator BUCKLEY. There is an enormous amount of research the Federal Government needs to do in the energy field, in particular. Looking at objectives down the line, in no circumstances would it be able to appeal to the private sector. I always wondered whether the Federal Government should go into something that is achievable in a 2- or 3-year time frame which is ideally suited to the private sector. You did speak of the necessity of guaranteeing that there will be a sufficient number of purchasers to create the incentive to come up with the car. The Federal Government, year-in and year-out, purchases a very large number of vehicles. I would assume over the next few years the needs that could be accommodated by the 50 miles per day vehicle within the Federal apparatus would be such that there could be a significant market assured for cars that met certain standards.

Mr. McCORMACK. This is specifically called for in the bill, for the various departments of government to purchase electric cars where they can. As you know, the U.S. Postal Service is purchasing some and ERDA purchased three of them for demonstration purposes, and the Department of Defense is considering purchasing some.

Senator BUCKLEY. One question, and perhaps later witnesses will be able to cast light on it, is might it not be sufficient for the Federal Government to say that we can guarantee purchases of 10,000 to 15,000 of these vehicles a day, to create all the incentives that are required for the private sector to focus their resources to come up with a necessary vehicle?

Mr. McCORMACK. I believe this is a question that needs to be explored and considered. I would suggest one of the factors in any such consideration has to be: we must be talking about vehicles that the average citizen can afford to buy, rather than those that are specified by the Federal Government; and they must meet safety standards that are adequate for street driving, neither more nor less.

Senator BUCKLEY. The Federal Government can say, we will buy a car of these specifications, so you have a guaranteed market.

Mr. McCORMACK. It might be larger also than what is called for in the bill. I think we have to explore this possibility to see what impact it has on our consideration. I do believe the demonstration out in the public of what an electric car can do in every day running around—I think the very presence of electric cars in our traffic—would have a very significant impact on people's thinking.

Senator BUCKLEY. Thank you very much.

Senator MOSS. I have just one more question I would like to ask you. Prof. John Haywood of the MIT Energy Laboratory stated in a letter concerning the demonstration program that he thought it was likely to produce disillusionment with electric vehicle operation. He also said it is likely to have the unfortunate consequence of focusing the Federal funds available for electric and battery research on short and interim term efforts, with severely limited potential, rather than on more realistically planned efforts to provide a viable option for the Nation in the longer run. What is your response to his criticism?

Mr. MCCORMACK. I respectfully differ from that position. In the first place, I believe that we have to emphasize that we are talking about second cars. We never have been talking about replacing high powered internal combustion engines, driving long distances at high speeds, or hauling heavy loads. I think this program has to recognize the type of vehicle we are talking about.

In view of the fact that we know today that we can actually build such vehicles and that they will actually serve the purposes that second cars are normally used for in this country, I do not believe that we are making a mistake in emphasizing this particular aspect of the program at this particular time.

As you are well aware, as we are all well aware, the most significant factor that has led to improvements in automobile technology, using internal combustion engines over the last 50 years, has been consumer interest. Consumer protection, consumer demand, has brought on competition, and higher standards of performance and design. This is the sort of thing that I think we want to depend upon. We need to stimulate the industry. We need to stimulate the interest. When small manufacturers, who are considering getting into business, and bankers who are asked to finance their operations, can look to the public and see a demand, a strong interest in the public for electric cars, then the money will be there and the innovations will be there, and the improved technologies will be there.

This is the most significant factor for improving the quality and performance as we go along, rather than having a long-range research and development program confined to the laboratory.

Senator MOSS. Well, thank you very much. I appreciate your appearance and your testimony, and I congratulate you on the fine job you performed in regard to this legislation on the House side.

Mr. MCCORMACK. Thank you very much, Mr. Chairman, and thank you, Mr. Buckley.

[The statement follows:]

STATEMENT OF HON. MIKE MCCORMACK, U.S. REPRESENTATIVE FROM WASHINGTON

Thank you, Mr. Chairman, I sincerely appreciate the invitation to appear before the Subcommittee and the opportunity to express my strong support for the Electric Vehicle Research, Development and Demonstration Act of 1975. I introduced the original bill in the House of Representatives, because I was persuaded of the definite need to accelerate the development and demonstration of electric vehicle technology so that the American people would soon have a viable option for their personal transportation which is both energy conserving and not dependent on imported oil. As I learned in greater detail about the full potential for electric vehicles during our Committee's consideration of this bill, I became firmly convinced of the wisdom of enacting the program into law. In my appearance here this morning, I hope I can help to instill in the members of this Subcommittee the same feeling of enthusiasm that I have for this exciting program.

Before going into the details of the bill itself, I should like to address some of the underlying reasons why we need such a research, development and demonstration program. As most of you are well aware, transportation uses consume about 50 percent of our petroleum, and more than one-third of our petroleum is imported. It also seems likely that we will simply run out of petroleum by the end of this century.

If one reads the national energy plan prepared by ERDA, it is clear that we are headed toward an economy which will be more heavily dependent on electrical energy generated from principally coal and nuclear fission, and later in this century, from geothermal and solar energy. We hope to have commercial nuclear fusion plants early in the next century.

The Electric Vehicle Research, Development and Demonstration Act of 1975 is not only consistent with this trend toward an electric economy, but it will actually help to foster this trend. By using electric vehicles we can replace imported petroleum with electricity produced from domestic sources. We will at the same time reduce the flow of petrodollars and develop the technology and economic infrastructure for a new transportation system in this Country, which retains the important characteristic of individual freedom of movement.

If economic, social, and technical factors had remained unchanged, the gasoline engine would probably have remained unchallenged far into the future. However, the mounting pressures to conserve petroleum and to reduce pollution from vehicle emissions are forcing a trend toward smaller vehicles for short urban commutes. Automotive propulsion systems, alternative to the internal combustion engine, must now be completely reevaluated; of all the alternatives, electric vehicles look the most promising.

Mr. Chairman, when considering what is and is not being done, and what can and cannot be done, that will have a significant impact in relieving the problems of the energy crisis, some programs have a much greater value than others, because they will have a significant impact in the near future. As we on the Science and Technology Committee have analyzed the energy crisis and tried to formulate solutions, we have picked pressure points where a small change in a technology that is socially, economically and environmentally attractive can make a big difference either in increasing our energy resource base or in reducing energy consumption.

In addition, we have sought pressure points where demands for critically short materials such as natural gas today or petroleum and gasoline in the near future can be reduced specifically, as compared to just reducing energy consumption generally. Switching to electric cars is such a program, particularly for second cars for urban commuting, and it has the advantage that Americans replace 10 percent of their cars each year, and that 40 percent of our cars are second cars.

I hope the members of the Subcommittee will appreciate that the initial objective of this legislation is to develop "second cars" for our citizens and specialized delivery vans for businesses and government agencies. This constraint, very frankly, is a technical one. The driving range of existing electric vehicles is about 60 miles. Thus they are amenable for immediate use in the 50 percent of those automobile trips which are less than 5 miles. In fact, a recent—1974—EPA study indicates that nearly 98 percent of daily driving of second cars could be met by an electric vehicle utilizing a single daily battery charge.

That same EPA report, entitled "Impact of Future Use of Electric Cars in the Los Angeles Region" also has significant calculations of potential oil savings. It states that short-range electric cars could replace 1 million, or 17 percent, of the cars in the Los Angeles Basin by 1980.

By the following decade, 1990, nearly half of the Los Angeles area cars could be electric. Replacements of similar fractions of our 100 million gasoline-powered vehicles throughout the Nation would have extremely salutory effects, both on our petroleum supplies and urban pollution. For example, if we replace 10 million gasoline-powered vehicles using only 2 gallons of gasoline per day with electric vehicles charged by coal or nuclear power plants, we will reduce oil consumption by 0.5 million bbl/day, which will represent about 3 to 5% of our domestic petroleum production by 1985 to 1990. This is one of three consumer-oriented things we can do to reduce oil and natural gas consumption without serious alteration of lifestyle. The others are to improve energy efficiency in gasoline-powered cars and in the home.

Widespread usage of electric vehicles would aid electric utilities in energy conservation because the electrical energy demands would be more uniform due to a predominance of recharging of batteries during late night and early morning hours. This would permit new more efficient power-plants to replace inefficient old power-plants presently operated to meet peak power requirements in the late afternoon and early evening.

The electric vehicle itself offers some prospect for energy conservation in heavily urban traffic, because no energy is used while the vehicle is stopped and because the energy lost in the form of heat during braking would be largely recoverable in an electric vehicle equipped with a regenerative braking system to store the recovered energy in the batteries, or perhaps in a flywheel.

In addition to conserving liquid fuels, electric vehicles can make a significant impact on air and noise pollution. The extremely complicated job of controlling millions of moving internal combustion engines—present sources of pollution—in a single city can be transferred to the more tractable problem of controlling and monitoring emissions from a few electric generating plants.

In 1967 a Department of Commerce study pointed out that the automobile was the largest single contributor to our national air pollution by weight. The Clean Air Act, Public Law 83–206, provided for research on motor vehicle pollutants. As a result, a program on advanced automotive power systems was initiated in the EPA. This program was transferred to ERDA by the Energy Reorganization Act of 1974.

Mr. Chairman, H.R. 8800, the Electric Vehicle Research, Development and Demonstration Act of 1975, establishes a 5-year, $160 million program for research, development and demonstration for electric vehicles under the Energy Research and Development Administration. The primary goal of this project will be to demonstrate the feasibility of electric vehicles, including the evaluation and demonstration of more than 7,500 vehicles over the next 5 years.

This bill provides for research and development programs to improve the existing electric vehicle technology. Batteries are a primary area in which the experts agree that major progress can be made in a short period of time. Dr. Edward David of Gould, Inc., testified before my Subcommittee that a new, lighter weight nickel-zinc battery could be developed at economically competitive prices within 2 years if a vigorous development program were initiated today. Other experts also feel that commercially feasible, highly superior replacements for the lead-acid battery can be developed within the time period of the 5-year program established by this bill.

However, we are faced with a sort of "chicken-and-egg" proposition. Before substantial private funding is invested to achieve major progress in batteries or other technical areas, there must be a sufficient market for the product. This is a primary justification for the Federal participation in electric vehicle research, development and demonstration. Through the R&D programs we promote the solution of the remaining technical problems which are currently preventing wider acceptance of electric vehicles.

Demonstration and maintenance programs would also be established. Planning grants and a loan guarantee program would be provided to allow small firms with problems in rising capital to bid competitively for the ERDA contracts and to establish themselves in the electric vehicle industry.

With the demonstration program we help remove the social and economic barriers by stimulating the interest of the American people in electric vehicles. The provisions of the bill will undoubtedly also encourage the investment of private capital for further R&D on electric vehicle technology and for the production of electric vehicles as well.

The article in the October, 1975 issue of *Consumer Reports* graphically demonstrates the need for the three-stage demonstration program included in H.R. 8800. The article stated that the two electric vehicles which were tested were not safe for driving on city streets, because a 30 m.p.h. collision would result in serious injury to the occupants. Under the three-stage demonstration program, ERDA is directed to develop, by examining the electric vehicles purchased in the first stage, performance criteria, including safety criteria, to be used in contracting during the second and third stages.

It should be emphasized that there will be considerable prospect for technology transfer from the electric vehicle program to other aspects of our lives. For instance, better batteries in terms of energy storage capacity will be directly applicable to storing electricity generated from solar energy sources such as wind generators and solar cells.

Mr. Chairman, I want to assure the members of this Subcommittee that ERDA is in fact the proper agency to administer this research, development and demonstration program. Electric vehicle development is a part of the broader Federal effort in alternative automotive fuels and power systems. The Advanced Automotive Power Systems program transferred to ERDA by P.L. 93–438 has been expanded into an Advanced Tansportation Power System. In fact, the House has authorized $27.5 million for this program in fiscal year 1976.

Under the provisions of P.L. 93–577 ERDA has been directed to perform not only research and development, but also demonstration programs. In my judgment we can only accelerate the commercialization of this important technology if there is the close coordination between research, development, and demon-

stration programs which occurs when one Federal agency has complete oversight of the program.

Mr. Chairman, it is clear that this Nation needs a concerted effort to develop and employ electric vehicles on a massive scale. This bill was unanimously approved by the Subcommittee on Energy Research, Development and Demonstration and by the Full Committee on Science and Technology.

On September 5, 1975, H.R. 8800 was approved by the House by the overwhelming margin of 308 for and only 60 against passage, which is enormously strong support for any bill authorizing a new $160 million program.

I commend H.R. 8800 to the members of this subcommittee with wholehearted enthusiasm. I hope that after your hearings you will be persuaded as I am that enactment of the Electric Vehicle Research, Development and Demonstration Act of 1975 is essential to provide a real alternative to the gasoline-powered automobile for the American people.

Senator Moss. Because our time constraints are going to limit us to a morning hearing, I am going to ask the witnesses who appear if they would attempt to summarize or capsulize their statements.

Now, in every instance, the complete written statement will be placed in the record and examined carefully by the members of the subcommittee and the full committee and by the staff, so you need not feel any of it will be left out. But we would like to have the highlights and emphasis on the part that you think ought to be particularly directed to the attention of the members of the subcommittee who are here this morning.

Our next witness will be Mr. Edward Campbell, executive secretary of the Electric Vehicle Council.

Mr. Campbell, would you come forward, please?

STATEMENT OF EDWARD A. CAMPBELL, EXECUTIVE SECRETARY, ELECTRIC VEHICLE COUNCIL

Mr. Campbell. Thank you, Mr. Chairman.

Senator Moss. We are very pleased to hear from you, sir.

Mr. Campbell. Thank you very much for giving me the opportunity to participate in this hearing.

I will skip over as much as I can of my prepared statement, including a description of the Electric Vehicle Council.

Senator Moss. We appreciate that.

Mr. Campbell. I would mention one thing about the council. We have sponsored a program to develop and put into use 170 battery-powered delivery vans which were delivered last year. So we have a little personal experience as well as we feel that we are reflecting the attitude of the industry.

Senator Moss. Are these vans concentrated in one city?

Mr. Campbell. No. All around the country.

Senator Moss. Thank you.

Mr. Campbell. Concerning S. 1632, the subject of these hearings, and the companion House bill, I would like to say at the outset that the council heartily endorses the goal of these bills, to demonstrate the feasibility of electric vehicles and compliments the committee on their foresight in initiating action to avoid depletion of petroleum reserves.

I think that even before we deplete the reserves, we have to consider we are presently escalating our imports of oil which have grown since the embargo from 25 to 38 percent.

However, oil use by the U.S. electric utilities is only 16 percent, which would give us an immediate advantage for electric vehicles.

I find it confusing to discuss our energy use in terms of millions of barrels per day. I would like to put it in simple numbers.

Considering the vehicles alone with either gasoline or battery, a number of studies have shown that the electric vehicle is 3.5 to 4 times as efficient as a gasoline vehicle.

As Mike McCormack said, there were papers on that subject presented at the House hearing which are available. One of them was by Dr. Salihi of the Otis Research Center.

When we go outside the vehicle to either gasoline or electricity, we find that 15 percent of the raw energy is lost in refining and distribution of gasoline while the efficiency of electric generating plants is about 32 percent.

When we apply these factors to the vehicle performance, we find that electric vehicles are still 32 percent more efficient in their use of energy than gasoline-powered vehicles.

That means if the gasoline vehicle used 100 units of energy, the electric would use 68. That is, if the electric industry used nothing but petroleum. But they only use 16 percent, as I mentioned before, and that is only 16 percent of those 68 energy units, and that figures out to 10.9.

Senator Buckley. May I ask a question?

Speaking about comparing the relative energy efficiency between electric and gas using automobiles, what miles per gallon figure are you using?

Mr. Campbell. Well, I am not approaching it that way. Engineers have analyzed every, what shall I say, system in the vehicles, for vehicles of different size, different speeds, and I have picked an average that they set forth.

Shall we say for an average size vehicle at moderate speed. The figures come out favorably at any speed, but it averages out to about 32 percent.

As I said, if we consider the utility use of oil as only 16 percent, it means that for every 100 units of petroleum used by gasoline vehicles less than 11 are used by the power plants providing the energy for the electricity.

So if we could suddenly transform all our road vehicles to electricity, we can cut petroleum use for transportation to one-ninth of what it is now.

I find that more meaningful than saying how many million barrels of oil we may save.

That prospect doesn't take into consideration the fact that most of the petroleum used by utilities is residual oil, the sludge that is left over after all the good parts have been refined out. Nor does it consider that the majority of electric vehicles can be charged in what to utilities are off-peak hours.

A study of automobile use reveals most of it is in the daylight hours during which utility peaks occur. If the car is in use at this time, it obviously can't be charged then and must be charged during off-peak hours.

We are often asked what that means for utilities and their customers. It means that the need for additional generating capacity is reduced, and that translates into less expensive electricity in the long run.

It also means we wouldn't have to add a lot of capacity in order to have electric vehicles.

Looking into the future, if in the year 2000 all cars were electric, it is estimated they would take between 6 and 10 percent of the expected total electric generation at that time.

In other words, it wouldn't have a tremendous impact.

Because we believe that in the long run electric vehicles are an imperative to our national policy of energy independence, we believe that we must start right now.

Consequently, we concur with the bill, that a Federal role is needed to demonstrate battery-powered vehicles on a substantial scale, to generate public awareness of their feasibility and social desirability, to support the development of an adequate maintenance and service network such as we now enjoy with gasoline-powered vehicles, to help remove legal or legislative impediments which may now stand in their way, and even to subsidize their sale. I think this is important. The time is ripe for electrics.

The rising cost of gasoline and the programs to conserve it have accelerated the trend to smaller cars, and wider public acceptance of lower performance vehicles.

This improves prospects for commercialization of present "state of the art" electric vehicles, as demands for size and performance lessen.

Consider that the currently offered Volkswagen "Rabbit," Honda "Civic" and Chevrolet "Chevette" are all smaller than the VW "Beetle" which we once considered a tiny car.

A prototype electric car introduced earlier this year by the Copper Development Association is about the same size as the Honda Civic, while a car being produced by the Electric Vehicle Associates of Cleveland is larger—about the size of the Mustang II.

I do not feel that the introduction into public use in the next 3 or 5 years of "state of the art" electric cars would affect public acceptance negatively.

Even the tiny Vanguard "Citicar" has not done that. Over 1,000 of these cars have been sold and, I'm told by Mr. Beaumont, are resulting in reorders from the dealers who have sold them.

The as yet relatively limited performance of electrics can still take care of a considerable portion of present automobile usage. The largest single category of auto use is commuting, which accounts for 34 percent of automobile petroleum use; 40 million workers drive an average of 94 miles and consume 290 million gallons of gas each week.

On a 5-day-week basis, 94 miles averages out to less than 20 miles a day, which would be no strain for any existing electrics.

The term "state of the art" electric vehicles presumes the use of lead-acid batteries. These batteries have been greatly improved since the days when electric cars were first introduced in the early 1900's, both as to energy output and life expectancy.

More improvements can be expected and, in fact, the Japanese are presently using prototype lead-acid batteries with energy densities as much as 50-percent greater than the best commercially available U.S. battery.

But there is a limit, of course, and writers of articles about electric vehicles bring up the subject of the "super battery" in the wings, usually a high temperature molten salt battery.

Laboratories working in this sector do not promise a street version in less than 10 years. We do not feel we can afford the luxury of sitting back to wait for the super battery.

Great strides can be taken in the electric vehicle field between now and 1985, not only in developing the vehicle powered with lead-acid batteries, but also in developing a support structure for its service and maintenance.

The matter of charging the batteries can be explored in a number of ways, also. Techniques have been patented for much faster charging, for instance, while there is another school of thought which believes that battery exchanging is the way to go.

One of the present contributors to the relatively high cost of electric vehicles is the concept of the battery as part of the capital equipment.

Some proponents of electric vehicles prefer to look upon the battery as fuel, like a tank of gasoline.

If batteries were available for exchange at something comparable to a gas station, and if they could be billed to the customer according to some unit of use, such as a per mile basis, they would be truly comparable to gasoline and not part of the capital expense.

I would like to say one other thing about the super battery. I do not feel battery research should constitute a major portion of expenditures under this bill. Partly for the reason I mentioned previously, namely we can cut oil use now with electric vehicles and partly because ERDA is already funding R. & D. in this area.

The lithium-sulphur program at Argonne National Laboratories was started by AEC and inherited by ERDA when the agency was formed at the beginning of this year, while the agency has recently announced contract awards to Dow Chemical Co. and Ford Motor Co. for the development of sodium sulphur batteries.

In considering what might be and probably should be done, we might look for a moment at two other countries, Germany and Japan.

Both these countries import over 90 percent of their petroleum and have a very important need for a substitute.

In Germany, the primary effort to develop electric vehicles has been sponsored by private industry under the leadership of the electric power company RWE, or Rhine-Westphalia Electric Co.; while in Japan the program has been sponsored by an agency of the government, the Ministry of International Trade and Industry, often referred to by its initials, MITI.

The German program was started in 1970, the Japanese in 1971. In both instances, the leadership organization established specific objectives as to types of vehicles to be developed and their target performance, and enlisted the assistance of manufacturers of motor vehicles, batteries and components to work together in developing prototypes which would meet the targets.

The programs have gone rather well and the prototypes are operating in considerable numbers in both countries.

This seems obviously to be a better approach than a hit or miss program dependent on what may chance to appear on the market.

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I might observe in passing that these two countries are the same ones who sold several million small cars in our country while our own manufacturers remained convinced that Americans did not want such small cars.

An alternative to our own development of electric vehicles would be to wait just a little bit until electric Toyotas and Volkswagens are ready for export and then we can play that whole scene over again.

I don't think we want to do that, and I don't think we can afford to postpone our own development.

The mention of the fact that such companies as Toyota, Nissan, Volkswagen and Mercedes Benz, Fiat and Zagato, Renault and Peugeot are seriously developing electric cars makes this an appropriate moment, I believe, to bring up the concept of the "electric vehicle industry."

I don't believe we are looking for a new industry to challenge our present automotive industry. What I think we are looking for is an alternative power source in our automobiles and commercial vehicles—a nongasoline source, if you will.

I believe that the manufacturing expertise and capability of our Detroit manufacturers is desperately needed if we are going to look to a future of millions of electric vehicles. I would hope that ERDA will strongly urge our automobile manufacturers to take part in this development from the ground floor up.

In considering the differences between S. 1632 and H.R. 8800, we note a strong emphasis in the final House bill on the inclusion of hybrids.

In view of the strong emphasis in the bill of finding a substitute for petroleum, we feel that the use of gasoline power as a secondary partner in a hybrid will dilute the effort needed for the development of electrics and postpone even longer the important reduction in the use of petroleum which can be effected by the introduction of straight electric cars.

As for other possible hybrids such as a flywheel/electric, it is our feeling that the flywheel as a commercially feasible product is farther away than even the super battery.

In the proposed act there are a lot of steps that are only sketchily outlined, naturally.

For instance, the Administrator would really have to draw up a proposal to which manufacturers could bid, and allow time for submission and acceptance of bids, contract awards, and so on. I do feel, however, that it would be possible to do the purchasing outlined in the bill within the time allotted.

I don't know about the "Buy American Act." I have to admit I am ignorant.

I understand that vehicles should be at least 50 percent made here. I don't know how one can tell that about a vehicle, electric or any other sort.

I think it would slow things down if the vehicles purchased had to be entirely made in the United States because many of the little manufacturers who are doing important experimentation in this field can't afford to make a whole vehicle and they buy small foreign chassis to work with.

I think that for the time being that would be desirable if they could use their products in this program.

The second part of the program, involving several thousand vehicles, I do believe would be possible because the prototypes already exist. They are either on the road or in somebody's laboratory.

It isn't as if we had to start today and develop a completely new item. In other words, I feel that it is feasible to do what the bill suggests.

I wish that the bill would include some provision for what will happen after it becomes enacted.

I think we will have reached a very desirable state 5 years from now, and I would like to think that a forward-looking plan would be at least mentioned beyond the end of this act.

On the subject of inhibiting legislation, there are a great deal of either Federal or State laws pertaining to the safety of vehicles which might be or obviously are inhibiting.

For instance, I read the requirements in the State of Oregon, and they are probably not peculiar, that require the four-wheel motor vehicle to be equipped with a muffler.

I think that sort of thing—there has to be a big study of that, to identify these things that would prevent an electric vehicle from being registered.

The bill provides for a study by the Secretary of Transportation on the current and future applicability of safety standards and regulations and I don't think that I need to list a lot of these things because a study will root them out.

The main thing would be to have an attitude or a Government policy which is designed to make it possible to put electrics on the road.

We believe the loan guarantee provision of H.R. 8800 would be beneficial to the development of electric vehicles because, as I mentioned before, there are a lot of small companies that have done some good work in this field, and we would like to see them get a chance to bring their technical contributions to a higher state of refinement or commercial feasibility.

We believe the outcome of this act could be a vehicle comparable in size and carrying capacity to the gasoline-powered subcompacts now being marketed, with a range of at least 100 miles and with top speed and acceleration capabilities sufficient to allow it to mix safely with gasoline-powered vehicles.

Such a vehicle already exists in prototype stage and should easily reach commercial feasibility during the life of this act.

We believe that such a vehicle could operate on 0.5 kWh/mile, which is the equivalent of 79.8 miles per gallon of gasoline on a straight Btu comparison. This would certainly be worthwhile.

There are some question marks as to what kind of data the figures are based on, but I think you can readily assume a vehicle operating under an equivalent of 80 miles per gallon would have to be a good deal cheaper.

The development of an electric vehicle has so many things going for it, we feel it is inevitable.

(1) It preserves the enjoyment of ownership of a personal vehicle.

(2) It provides a way to utilize more abundant energy resources—coal and nuclear—as a substitute for scarce resources—oil.

(3) It uses energy more efficiently than the conventional internal combustion engine car.

(4) It lessens the urban pollution problem associated with automobiles, as well as the noise.

(5) It provides an offpeak use of electricity so as to use generating facilities more efficiently.

In this latter connection, it also provides for the substitution of electric energy for petroleum while minimizing the need for new generating equipment.

At least as many advantages can also be mustered for the commercial electric vehicle, especially the multistop, short-range urban delivery vehicle, which uses no "fuel" while it is standing still.

This type of vehicle, and especially those used in so-called "closed loop" missions such as postal delivery vehicles, are much more feasible with state-of-the-art equipment than personal cars.

We have placed an emphasis on the car in these remarks, not purposely overlooking the commercial applications, because the problem is bigger. There are at least five times as many cars, which use a great deal of our oil and create a great deal of ground-level air pollution.

In a statement issued 3 weeks ago by the Secretary of Transportation, the car is described this way: "The automobile is and will continue to be the most universally accepted form of transportation in America. It is the most flexible and responsive mode and provides the greatest freedom of mobility."

I believe few people would quarrel with that statement. And what it says to me is that if we are going to protect our environment, become energy independent, and at the same time hang on to "the most universally accepted form of transportation," we must foster the development of the electric car.

That is why we at the Electric Vehicle Council are strongly behind this bill and hope that this committee will report favorably on it.

Thank you for giving me this opportunity to express our views.

Senator Moss. Thank you, Mr. Campbell, for your statement.

How long has the council been organized?

Mr. Campbell. Since 1968, Senator.

Senator Moss. I see.

What is the size of its membership?

Mr. Campbell. We have several hundred members, partly electric power companies and partly manufacturers, individuals, other associations, and many of these members are from foreign countries.

Senator Moss. Are you a trade association or do you carry on research and development work?

Mr. Campbell. I think it could be better described as a trade association.

Senator Moss. We appreciate your testimony. We are glad to be informed of some of the things that you have achieved with your council, and the comparisons you have made in regard to the efficiency of electric-powered vehicles as compared to combustion engines have been very interesting.

You, I take it, agree with the thrust of the bill that we should focus on one second car, a small commuter-type car or short-haul delivery vehicle?

Mr. CAMPBELL. Yes.

Senator MOSS. You do not believe the technology is in sight yet for a long-range, high-speed car?

Mr. CAMPBELL. No. I think it is in the mind of the scientist, but as far as our present——

Senator MOSS. The next 5 to 10 years—it isn't there?

Mr. CAMPBELL. No.

I also feel the trend—this isn't just a feeling—the trend is away from such cars and by 10 or 15 years from now the high-powered car will be pretty out of style.

But I do believe that by the end of the century electric vehicles will be able to perform anything that we can expect from a car. But that is 25 years.

Senator MOSS. Thank you.

My colleague from New York may have a question or two.

Senator BUCKLEY. I would just like to address myself to one area of your testimony. You spoke of the need to move toward a super battery.

A Congressman has testified, and I quote, "A lighter weight, nickel-zinc battery, could be developed at economic competitive prices within 2 years if a program were initiated today."

Is this the type of battery that fits the category of super battery? If so, is this 2-year time frame in your judgment a realistic one?

Mr. CAMPBELL. First of all, Senator, no; that is not a real super battery we were talking about. That is an intermediate stage which could give us perhaps a doubling of the present capacity.

We need much more than double, if we were going to be comparable with gasoline.

Not to disagree with Mike McCormack, the company which said they would have the nickel-zinc battery developed in 2 years did not mean on the shelf, ready to be used. I think they feel that it will be as much as 5 years before they can drop it into a car. But even 5 years is within our thinking.

In other words, 5 years from now we can have a type of battery which will give us a little more than we now get, but we feel from studying the whole situation that in the 10 years the lead-acid battery will still be the primary source.

So we have to gear our expectations on what can be done with that.

Senator BUCKLEY. Thank you very much.

Senator MOSS. Thank you, Mr. Campbell. We do appreciate your testimony.

[The statement follows:]

STATEMENT OF EDWARD A. CAMPBELL, EXECUTIVE SECRETARY, ELECTRIC VEHICLE COUNCIL

Gentlemen, thank you for the opportunity to participate in this hearing. I am the Executive Secretary of the Electric Vehicle Council, and I'll introduce my remarks with a few words as to what the Council is. The Electric Vehicle Council was formed in 1968 by the Edison Electric Institute, the principal association of America's investor-owned electric utility companies. The objective of the Council is "to advance the use of electricity in transportation."

Today the Council is an international organization, with members from companies in 19 countries, in the electric utility, transportation, electrical equipment and battery industries. In addition, EVC membership includes other associations and a large number of individuals, including representatives of universities, research laboratories, government agencies and others. In the United States, electric power suppliers are members of EVC by virtue of their membership in Edison Electric Institute or in the American Public Power Association.

The Council is administered by a staff maintaining headquarters in New York City, and is governed by a nine-man Executive Board currently chaired by Mr. F. J. Port, president of ESB Incorporated. The other eight members of the Board include four utility company presidents, three officers of manufacturing companies and the director of a trade association.

Among its activities, the Council sponsored a program to develop, produce and put into use 107 battery-powered delivery vans, which were delivered to users during calendar 1974. The Council sponsors a biennial International Electric Vehicle Symposium, the most recent of which was held in Washington, D.C. in February, 1974. We've published several market research studies related to electric vehicles and we sponsor the quarterly magazine, Electric Vehicle News.

Concerning S. 1632, the Bill which is the subject of these hearings, and its companion bill H.R. 8800, I would like to say at the outset that the Council heartily endorses the primary goal of these bills, to demonstrate the commercial feasibility of electric vehicles. We compliment the Committee on their foresight in proposing federal action now, in anticipation of our eventual depletion of petroleum reserves and the gradual shift to primary dependence on electric power generated by coal and nuclear.

In fact, we have a more immediate problem than "the eventual depletion of our petroleum reserves," and that is our present shortfall, which causes the escalation of oil imports at very high prices. In spite of the nation's "energy consciousness" since the oil embargo, our imports have grown from 25% last year to 38% at this time.

The mix of fuels used by the nation's electric utilities is only 16% petroleum, which would give us an immediate advantage with electric vehicles.

I personally find it confusing to discuss our energy use in terms of millions of barrels of oil per day, so I'd like to put electric vehicle use in focus with some simpler numbers.

Considering the vehicle alone, with its on-board power source of either gasoline or electric energy, a number of studies have shown the electric to be 3.5 to 4 times as energy-efficient as the gasoline-powered vehicle. One of the papers on this subject, by Dr. J. T. Salihi of the Otis Research Center, was submitted to the House committee which conducted hearings on H.R. 5470.

Outside of the vehicle, we find that 15% of the raw energy is lost in refining and distribution of gasoline, while the efficiency of electric generating plants is about 32%. When we apply these factors to the vehicle performance, we find that electric vehicles are still 32% more efficient in their use of energy than gasoline-powered vehicles.

That means that if the gasoline vehicle used 100 units of energy, the electric would use 68 units. That is, IF the electric industry used nothing but petroleum to generate. But they only use 16% oil, as I mentioned earlier. Therefore, only 16% of those 68 energy units come from oil. That figures out to 10.9 units.

So, for every 100 units of petroleum used by gasoline vehicles, less than 11 units of petroleum are used by the power plant providing the energy for the electric vehicle. If we could suddenly transform all our road vehicles to electric, then, we could cut our petroleum use for transportation to 1/9 of what it is now. And that prospect doesn't take into consideration the fact that most of the petroleum used by utilities is residual oil—the sludge that's left after all the good parts have been refined out. Nor does it consider that the majority of electric vehicles can be charged in what for utilities are off-peak hours.

A study of automobile use reveals that most of it occurs in daylight hours, during which utility peaks occur. If the car is in use during this time, it obviously can't be charged then, and must be charged during off-peak hours.

What does that mean for utilities and their customers? It means that the need for additional generating capacity is reduced, and that translates into less expensive electricity in the long run.

In that connection, and looking off into the future, if in the year 2000 all cars were electric, it is estimated they would take between 6 and 10% of the expected total electric generation at that time.

Because we believe that, in the long run, electric vehicles are an imperative to our national policy of energy independence, we believe that we must start right now. Consequently, we concur with the Bill, that a federal role is needed to demonstrate battery-powered vehicles on a substantial scale, to generate public awareness of their feasibility and social desirability, to support the development of an adequate maintenance and service network such as we now enjoy with gasoline powered vehicles, to help remove legal or legislative impediments which may now stand in their way, and even to subsidize their sale. I think this is important. The time is ripe for electrics. The rising cost of gasoline and the programs to conserve it have accelerated the trend to smaller cars, and wider public acceptance of lower performance vehicles. This improves prospects for commercialization of present "state of the art" electric vehicles, as demands for size and performance lessen. Consider that the currently offered Volkswagen "Rabbit," Honda "Civic" and Chevrolet "Chevette" are all smaller than the VW "Beetle" which we once considered a tiny car. A prototype electric car introduced earlier this year by the Copper Development Association is about the same size as the Honda Civic, while a car being produced by the Electric Vehicle Associates of Cleveland is larger—about the size of the Mustang II.

I do not feel that the introduction into public use in the next three or five years of "state of the art" electric cars would affect public acceptance negatively. Even the tiny Vanguard "Citicar" has not done that. Over 1,000 of these cars have been sold and, I'm told by Mr. Beaumont, are resulting in re-orders from the dealers who have sold them.

The as-yet relatively limited performance of electrics can still take care of a considerable portion of present automobile usage. The largest single category of auto use is commuting, which accounts for 34% of automobile petroleum use. Forty million workers drive an average of 94 miles and consume 290 million gallons of gas each week.

On a 5-day-week basis, 94 miles averages out to less than 20 miles a day, which would be no strain for any existing electrics.

The term "state of the art" electric vehicles presumes the use of lead-acid batteries. These batteries have been greatly improved since the days when electric cars were first introduced in the early 1900's, both as to energy output and life expectancy. More improvements can be expected and, in fact, the Japanese are presently using prototype lead-acid batteries with energy densities as much as 50% greater than the best commercially available U.S. battery.

But there is a limit, of course, and writers of articles about electric vehicles inevitably bring up the subject of the "Super Battery" in the wings, usually a high temperature molten salt battery. Laboratories working in this sector do not promise a street version in less than 10 years. We do not feel that we can afford the luxury of sitting back to wait for the Super Battery. Great strides can be taken in the electric vehicle field between now and 1985, not only in developing the vehicle powered with lead-acid batteries, but also in developing a support structure for its service and maintenance. The matter of charging the batteries can be explored in a number of ways, also. Techniques have been patented for much faster charging, for instance, while there is another school of thought which believes that battery-exchanging is the way to go.

One of the present contributors to the relatively high cost of electric vehicles is the concept of the battery as part of the capital equipment. Some proponents of electric vehicles prefer to look upon the battery as fuel, like a tank of gasoline. If batteries were available for exchange at something comparable to a gas station, and if they could be charged to the customer according to some unit of use, such as a per mile basis, they would be truly comparable to gasoline and not part of the capital expense.

Before passing on to another point, I'd like to jump back for a minute to the Super Battery. I do not feel that battery research should constitute a major portion of expenditures under this Bill, partly for the reason I mentioned previously, that I don't feel that electric development and demonstration should be postponed on that account. But also partly because ERDA is already funding r&d in this area. The lithium-sulphur program at Argonne National Laboratories was started by AEC and inherited by ERDA when the agency was formed at the beginning of the year, while the agency has recently announced contract awards to Dow Chemical Company and Ford Motor Company for the development of sodium-Super Batteries.

In considering what might be and probably should be done, we might look for a moment at two other countries, Germany and Japan. Both these countries

import over 90% of their petroleum. In Germany, the primary effort to develop electric vehicles has been sponsored by private industry under the leadership of the electric power company RWE, or Rhine-Westphalia Electric Company, while in Japan the program has been sponsored by an agency of the government, the Ministry of International Trade and Industry, often referred to by its initials, "MITI." The German program was started in 1970, the Japanese in 1971. In both instances, the leadership organization established specific objectives, as to types of vehicles to be developed and their target performance, and enlisted the assistance of manufacturers of motor vehicles, batteries and components to work together in developing prototypes which would meet the targets. The programs have gone rather well and the prototypes are operating in considerable numbers in both countries.

This seems obviously to be a better approach than a hit or miss program dependent on what may chance to appear on the market. I might observe in passing that these two countries are the same ones who sold several million small cars in our country while our own manufacturers remained convinced that Americans did not want such small cars. An alternative to our own development of electric vehicles would be to wait just a little until electric Toyota's and Volkswagens are ready for export and then we can play that whole scene over again.

The mention of the fact that such companies as Toyota, Nissan, Volkswagen and Mercedes Benz, Fiat and Zagato, Renault and Peugeot are seriously developing electric cars makes this an appropriate moment, I believe, to bring up the concept of the "electric vehicle industry." I don't believe we are looking for a new industry to challenge our present automotive industry. What I think we are looking for is an alternative power source in our automobiles and commercial vehicles—a non-gasoline source, if you will. I believe that the manufacturing expertise and capability of our Detroit manufacturers is desperately needed if we are going to look to a future of millions of electric vehicles. I would hope that ERDA will strongy urge our automobile manufacturers to take part in this development from the ground floor up.

In considering the differences between S. 1632 and H.R. 8800, we note a strong emphasis in the final House bill on the inclusion of hybrids. In view of the strong emphasis in the Bill on finding a substitute for petroleum we feel that the use of gasoline power as a secondary partner in a hybrid will dilute the effort needed for the development of electrics and postpone even longer the important reduction in the use of petroleum which can be effected by the straight electric cars. As for other possible hybrids, such as a flywheel/electric, it is our feeling that the flywheel as a commercially feasible product is farther away than even the Super Battery.

We believe that the outcome of this Act could be a vehicle, comparable in size and carrying capacity to the gasoline-powered sub-compacts now being marketed; with a range of at least 100 miles; and with top speed and acceleration capabilities sufficient to allow it to mix safety with gasoline-powered vehicles. Such a vehicle already exists in prototype stage and should easily reach commercial feasibility during the life of this Act. We believe such a vehicle could operate on .5 KWH/mile, which is the equivalent of 79.8 miles per gallon of gasoline on a straight BTU comparison. This would certainly be worthwhile.

The development of an electric personal vehicle has so many things going for it, we feel it is inevitable: (1) It preserves the enjoyment of ownership of a personal vehicle; (2) It provides a way to utilize more abundant energy resources (coal and nuclear) as a substitute for scarce resources (oil); (3) It uses energy more efficiently than the conventional internal-combustion-engine car; (4) It lessens the urban pollution problem associated with automobiles, as well as the noise; and (5) It provides an off-peak use of electricity so as to use generating facilities more efficiently. In this latter connection, it also provides for the substiution of electric energy for petroleum while minimizing the need for new generating equipment.

At least as many advantages can be mustered for the commercial electric vehicle, especially the multi-stop, short-range urban delivery vehicle, which uses no "fuel" while it is standing still. This type of vehicle, and especially those used in so-called "closed loop" missions, such as postal delivery vehicles, are much more feasible with state-of-the-art equipment than personal cars. We have placed an emphasis on the car in these remarks, not purposely overlooking the commercial applications, because the problem is bigger: there are at least

five times as many cars, which use a great deal of our oil and create a great deal of ground-level air pollution.

In a statement issued three weeks ago by the Secretary of Transportation, the car is described this way: "The automobile is and will continue to be the most universally accepted form of transportation in America. It is the most flexible and responsive mode and provides the greatest freedom of mobility." I believe few people would quarrel with that statement. And what it says to me is that if we are going to protect our environment, become energy independent and at the same time hang on to "the most universally accepted form of transportation," we must foster the development of the electric car. That's why we at the Electric Vehicle Council are strongly behind this bill and hope that this committee will report favorably on it.

Thank you for giving me this opportunity to express our views.

Senator Moss. I am going to ask Dr. Bernard Baker if he would come forward and be our next witness.

STATEMENT OF DR. BERNARD BAKER, PRESIDENT, ENERGY RESEARCH CORP., DANBURY, CONN.

Dr. Baker. Mr. Chairman, I am president of Energy Research Corp., a subsidiary of St. Joe Minerals Corp., a major lead and zinc producer in the United States. Our company has been active in the energy conversion and storage field for the past 6 years. I have a B.S. and M.S. degree from the University of Pennsylvania and a Ph.D. degree from Illinois Institute of Technology in chemical engineering.

The previous gentlemen have testified on a number of matters that are in line with my statement here. I will go over them.

There is no question that there would be a tremendous saving in oil production. My figures are in agreement with the numbers given. I should like to say, another way of putting it is in terms of a favorable balance of payments of $4 billion a year which would accrue in using electric vehicles. I don't think this point was made. I think it is important, I should like to say, that we basically support this bill, and we think it is a very important step in developing an electric vehicle which would be competitive with the internal combustion engine. It is a very desirable thing for the country. It would be a mistake to think that the electric vehicle is across-the-board competitive with the internal combustion engine car. It is not. It will be for the period of this bill and many years thereafter, a limited-range vehicle, perhaps, with limited performance.

Nevertheless, there does seem to be a great many areas where the vehicle could be used and used effectively and economically. I think some of those areas are delivery vans, in-city cars, commuter cars, suburban runabouts, intra and intercity buses and so forth.

This could represent a great saving to the consumer provided that the vehicles are developed in a rational way. I think, it is important, then, that the bill be directed toward achieving both technically and financially viable electric vehicles.

My expertise lies in the energy storage area. The battery car is not a new idea. At the turn of the century, it was pioneered by Thomas Edison, but in times of abundant fuel it was passed by the ICE. Over the past 100 years very little has emerged from the battery industry that would change that situation. The lead-acid battery, which is commonly used in starting, lighting, ignition, and off-the-

road electric transportation constitutes about 75 percent of the battery market in the United States. Probably this is the battery to be used in the first two parts of this act.

We think there is room for improvement in the lead-acid battery, but perhaps only marginally, perhaps 30 percent, which would mean an increase in energy density to about 18 watt hours per pound. This would convert into a vehicle with a range of 60 miles and limited high-speed performance.

Nevertheless, the great experience of this industry and the availability of lead within the United States' borders, make it a viable and probably continuing-use battery in the electric vehicle scheme.

I think a great deal of information would be derived using lead-acid batteries in the initial phases of the bill. I would suggest that the second part of the bill be delayed by about 6 months so that the information can be digested for the third part of the bill.

I would also suggest that the second part should include a number of vehicles with advanced prototype battery systems so the Administrator can learn about the performance of improved electric vehicles.

I think it is really the third purchase specified in the bill where we can expect the impact from improved battery technology to be made. I would like to briefly review battery development in the United States to put this in perspective.

In the late 1940's the nickel-cadmium battery was developed. This represented tremendous improvement in cycle life, that is the number of times batteries can be reused. The energy density was about the same and the cost was much higher than lead batteries. In the 1950's the silver-zinc battery was developed. This battery had considerably higher energy density than either the lead-acid or nickel-cadmium battery but its uses were limited to only very special purpose applications.

Early in the 1970's, a number of companies in the United States, Japan, western Europe, and the Soviet Union began the development of a nickel-zinc battery. This battery, as the name suggests, is a combination of the aforementioned two batteries. It has high-energy density, relative to these other batteries, and could provide the basis for electric vehicles in this country through the year 1990 and onward, and certainly is the leading candidate for achieving the goals under this act.

I think within the time frame of the current act, that is 5 years, it is reasonable to anticipate that 100-to-200-percent improvement in energy density could be achieved in electric vehicles by the use of this battery. What this would mean would be the vehicles so developed would have a range of about 150 miles, and a top speed of 55 miles an hour. They would, therefore, extend the practical use of electric vehicles beyond that which is currently achievable with lead-acid batteries. We are not really talking here about a far-out technology. We are talking about the need to improve technology. It is not something we have to wait 20 years to bring about. I think the achievement of a cost-effective life cycle for this battery may take somewhat longer, but it is reasonable to project a thousand cycles in the early 1980's. This would translate into a battery system that could be used for 100,000 to 150,000 miles before it had to be replaced.

I think it is important to comment on the availability of nickel and zinc. They are abundantly available within the North American Continent. It is interesting to note that if we were to bring 20 million nickel-zinc powered cars on to the American highways within a 10-year period this would require the expenditure of about $3½ billion, mostly with our Canadian neighbors.

However, once this material would be in the United States, it is completely recyclable and reusable and would become part of the national wealth.

This would compare with $22 billion of nonreusable petroleum products over the same period and approximately $4 billion of nonreusable petroleum imports every year thereafter.

The nickel-zinc battery is still at an early stage of development and many technical problems remain, but we think they are the type of technical problems that will be responsive to a research and development effort on the part of the administrator.

Finally, I would like to comment that, we think that R. & D. in the battery area is the major necessity under this bill. It is also necessary to create an atmosphere within which the electric vehicle will have the best chance to succeed.

That may mean the initial relaxation of some performance requirements, as well as some economic incentives, perhaps via a tax rebate and by favorable utility rate structures, for electric vehicle users. But I think these terms would be advantageous to the country as a whole, because of the impact in such areas as pollution and energy conservation and the more efficient operation of our electric utility system.

Senator Moss. Thank you, Dr. Baker. Your full statement and the supporting paper and the tables will all be in the record. We are very pleased to have your testimony.

What is the likely cost of this advanced battery that you say we might have available in 5 years?

Dr. Baker. I think the battery could be developed for a cost of 5 cents a watt hour, translating into about $1,000 for a typical passenger vehicle. There is supplemental information to that effect supplied with my testimony.

Senator Moss. So, if you had a rotating system of some kind, rather than recharging, then you would have to have two or more of them. Is that right?

Dr. Baker. That is right. This is the type of battery we would envision being recharged over, say, an overnight period. I think one of the interesting aspects of electric vehicles is that it is sort of a load leveler. It could be used to absorb the Nation's electric utility capacity during offpeak periods. We would envision this battery being charged over a 4-to-8-hour period, during the evening hours.

Senator Moss. So you would have a plug in your garage and a clock that would turn it on, say, at midnight, when the demand was lowest on the power system?

Dr. Baker. That is the idea; yes.

Senator Moss. Do you believe the funding levels to facilitate research and development in the two bills before the committee are adequate?

Dr. BAKER. I think the situation here is we are up against a very big and well-developed industry in terms of the internal combustion engine. Comparison with that industry, the numbers are small. On the other hand, I think a well-balanced program focusing attention on the right places, as this bill, could go a long way to getting the electric vehicles on the road. I think battery research and development is an important aspect of this bill.

Senator MOSS. Do you think that battery research and development is the most important aspect or do you believe there are other aspects where we ought to concentrate the R. & D. work?

Dr. BAKER. I think the majority should be in the energy storage area. I think the energy storage device we are looking for is the battery as opposed to mechanical devices or a fuel cell.

I also agree with Mr. Campbell that the hybrid concept is not a particularly good one. That is my feeling.

Senator MOSS. Well, thank you, Dr. Baker, for your testimony. It was particularly interesting and most helpful to us.

[The statement and additional materials follow:]

STATEMENT OF DR. BERNARD BAKER, PRESIDENT, ENERGY RESEARCH CORP.

My name is Bernard S. Baker and I am president of Energy Research Corp., a subsidiary of St. Joe Minerals Corp. Our company has been active in the energy conversion and storage field for the past six years. I hold BS & MS degrees from the University of Pennsylvania and a Ph. D. degree from Illinois Institute of Technology all in Chemical Engineering.

Congressional bills S. 1632 and H.R. 8800 are addressed to an important aspect of U.S. energy and transportation policy. The Electric Vehicle Research, Development & Demonstration Act of 1975 would represent a significant first step toward creating an electric vehicle which could compete with the conventional internal combustion engine (ICE) vehicle in many areas. Among some of the benefits of such competition would be reduction of air pollution—by localization at the central station, conservation of liquid hydrocarbon fuels—eventual substitution of 20% of the total passenger vehicles with electrics would represent a fuel savings of approximately 300 million barrels per year, improvement of U.S. balance of payments as a result of such conservation—4 billion dollars per year, and enhancement of the efficiency of our electric utilities by increasing their load factor during otherwise low use periods—by as much as 25%. Further, since electric vehicles will depend on domestic resources rather than foreign they should create employment for American Labor.

If the desired results of this legislation are to be derived it is important that the correct steps be taken to ensure that effective development of technically acceptable and economically viable electric vehicles occur. To achieve this attention must be given to establishment of realistic goals in all aspects of vehicle and subsystem design. My own particular field of expertise lies in the energy storage and energy conversion subsystems and I will limit my remarks to those areas.

In establishing goals, the electric vehicle cannot be viewed as an across the board competitor to the IC car. During the time period covered by the bill and for the many years thereafter, the electric vehicle will be a limited range vehicle which will be especially well suited to specific operating regimes but incapable of long range operation and lacking the flexibility of the IC engine. In spite of these limitations, however, there are a large number of potential applications for electric vehicles in which they will be of direct benefit to the consumer and the environment—that is delivery vans, incity cars, commuter cars, suburban runabouts and station cars, intercity commercial fleets and intra and intercity buses. These could represent a substantial number of vehicles provided that the initial purchase price and operating costs are such that the incentives overcome the technical limitations.

I believe that it is critical, therefore, that the bill be aimed at selecting practical operating regimes suited to electric vehicles and then developing and demonstrating both the technology and economics of electric vehicle systems to satisfy the requirements of specific practical end use applications—which will probably mean different combinations of performance and cost for different uses.

It is my feeling that the single most important technological hurdle to be overcome in the development of an acceptable electric vehicle lies with the energy storage subsystem. For practical engineering and economic reasons this subsystem must be in the form of a secondary (rechargeable) battery as opposed to a mechanical device or fuel cell.

The battery powered vehicle is an old idea founded at the turn of the century by such entrepreneurs as Thomas A. Edison. It was quickly surpassed however by the internal combustion engine in an age of cheap and plentiful fuels.

Very few new developments have emerged from the battery industry in the last 100 years to change or enhance the competitive position of the electric car vis a vis the ICE.

The lead-acid battery commonly used for starting, lighting, ignition and some off-the-road industrial traction vehicles, and golf carts represents 75 percent of the U.S. battery market and certainly is the most likely candidate for the first two purchases under the Act. While some improvement may be anticipated in lead battery technology, perhaps 30% in energy density to 18 Whrs/lb, this battery will at best represent a limited performance electric vehicle with a practical range of up to 60 miles and modest speed and performance capability. Nevertheless, the reasonable and established economics, the abundant availability of lead within the United States and established production lines mean that this battery will play an initial and perhaps continuing role in electric vehicles provided it is not forced into applications for which it is obviously unsuited. A hundred years of experience is not readily put aside but clearly the lead-acid battery is asymptotically approaching its technical limits.

Much information on other components can be developed during the first two purchases that will enhance electric vehicle development. It would be advisable to extend the second purchase date by 6 months to 21 months in order to give time to assimilate the information from the first buy in setting specifications and guide lines for the second buy. Also the second buy should include a reasonable number of vehicles containing advanced battery prototypes to gain experience for the third purchase. To have these prototype batteries available a research and development effort must be initiated early in the project by the Administrator.

It is really to the third purchase specified in the bill that the first substantial impact of improved battery technology can be expected. Historically it might be reasonable to recall that the first new rechargeable battery to obtain any widespread use in this century was the nickel-cadmium battery which emerged in the late 1940's. This battery represented a substantial improvement in cycle life over the lead-acid battery but showed only marginally improved energy density characteristics and was considerably more expensive to produce.

In the 1950's the silver-zinc battery was developed representing a major improvement in the energy density of secondary batteries but the use of silver clearly limited its application to special situations.

In the early 1970's the development of the nickel-zinc battery, a combination of these latter two systems, was initiated in the U.S. and elsewhere and it is my belief that this system is the leading candidate for achieving the goals and benefits of this Act. A continuously improving nickel-zinc battery could form the basis for electric vehicles through 1990 at which time some of the more exotic higher energy density batteries currently being researched may be expected to be available. A comparison of various battery systems is attached in Table 1.

Within the time frame of the current Act it is reasonable to expect nickel-zinc batteries to show a 100% to 200% improvement in energy density characteristics over existing lead-acid or nickel-cadmium battery systems. Such batteries would provide for passenger vehicles with ranges up to 150 miles and top speed capabilities of 55 MPH, thereby extending the practical economic use of electric vehicles beyond those established with the lead acid battery.

Achievement of cost effective cycle life characteristics may take a longer time to realize but 1000 cycles corresponding to 100 to 150 thousand miles seems a reasonable goal by the early 1980's. The nickel and zinc raw materials are abundantly available in North America and, in a traction battery configuration, readily recycleable and present no objectionable environmental or ecological problems.

It is interesting to note that to bring 20 million nickel-zinc powered cars onto American highways over a 10 year period would cost the country about 3.5 billion dollars in imported materials mostly from Canada. These materials are almost totally reuseable in perpetuity once they have been imported. This compares with an equivalent purchase of 22 billion dollars of oil for ICE vehicles over the same period and $4 billion per year thereafter none of which, of course, is reuseable.

The nickel-zinc battery is at an early stage in its development cycle and technical problems remain. It would appear however that they are the type of problems which will respond to research and the development efforts by the Administrator.

In addition to R. & D. it will be necessary to create an atmosphere within which the electric vehicle will have the best chance to succeed. This may mean initial relaxation of performance requirements as well as economic incentives via tax rebates and favorable utility rate structures for electric vehicle users. These incentives must be viewed as advantageous to the nation as a whole because of the benefits delineated at the beginning of the statement.

TABLE 1.—CHARACTERISTICS OF SECONDARY BATTERIES—20 KILOWATT HOUR BATTERY

Battery type	Weight in pounds	Estimated price	Estimated cycle life
Lead-acid	1,700	$800	1,000
Nickel-cadmium	1,400	6,000	3,000
Nickel-iron	1,000	2,000	1,000
Silver-cadmium	800	11,000	500
Nickel-zinc	670	1,000	1,000
Zinc-chlorine	600	(1)	(1)
Silver-zinc	444	10,000	400
Zinc-oxygen	222	(1)	1,000
Organic	200	(1)	(1)
Sodium sulfur	200	(1)	1,000

[1] Not available commercially—still in R. & D. stage.

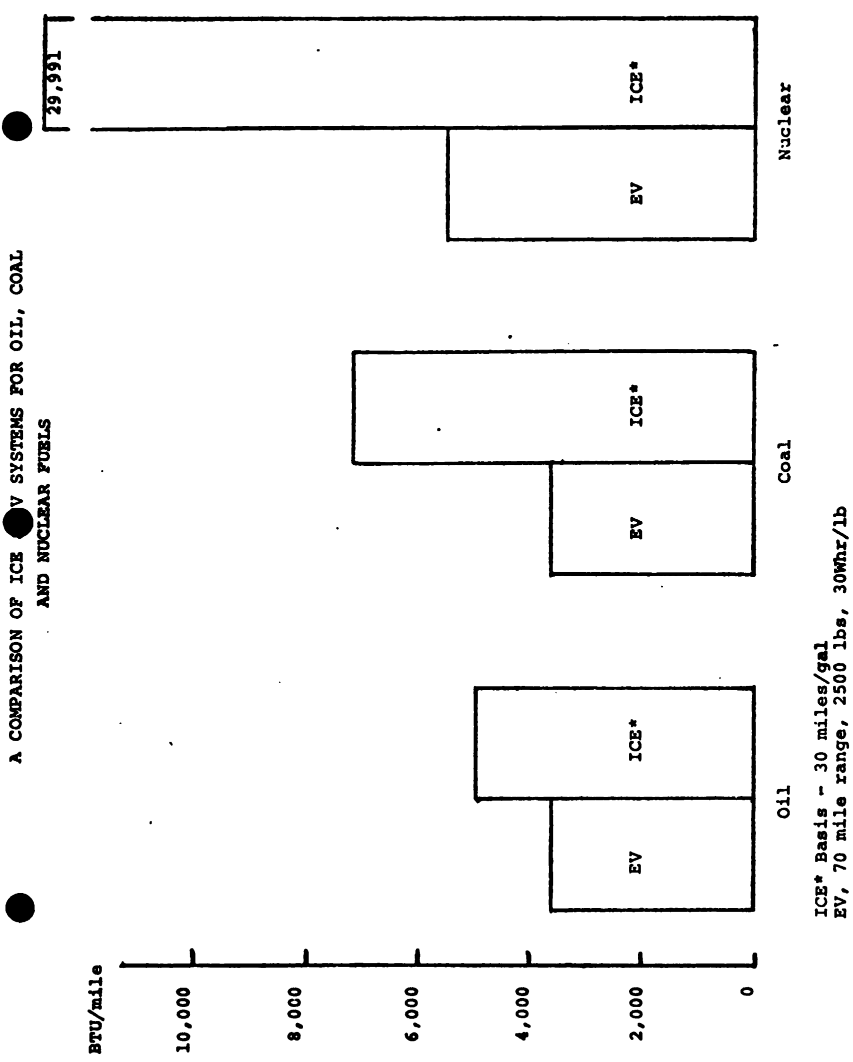
Case for Electric Vehicles

As hydrocarbon fuel prices rise and these fuels become more scarce their use in transportation, especially road vehicles, becomes less attractive to the consumer, the United States and the world. The American consumer is concerned with his out of pocket cost for gasoline and related fuels, the U.S. Government as well as the people have concerns over the balance of payments deficits caused by importation of these fuels. The world at large sees the massive consumption of these exhaustible fuels in the motor cars of the western world as a threat to their existence depriving them of resources needed for food and other essential material consumption.

Alleviation of this serious problem is difficult. Unlike central station power where coal or nuclear fuels can be substituted for fluid hydrocarbon fuels the transportation problem is not so directly solved.

Two types of solutions can be offered to the road transportation problem, synthetic fuels or electric traction. Electric traction seems to provide an overwhelming better alternative to synthetic fuels since it results in more efficient use of our coal resources and is more directly adaptable to using nuclear fuel via nuclear powered central stations.

This is vividly shown in the first bar chart where three scenarios are compared. This chart first shows relative efficiency or miles per unit of energy for gasoline powered and electric powered vehicles accounting for all the inefficien-



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cies in both systems. Next the situation is compared for synthetic fuels where coal is the source of hydrocarbon. This situation is even less attractive for the internal combution engine (ICE) because of the energy loss in converting coal to liquid fuels. Even if coal resources were unlimited, the labor, capital and transportation facilities associated with mining coal dictate its most efficient end use.

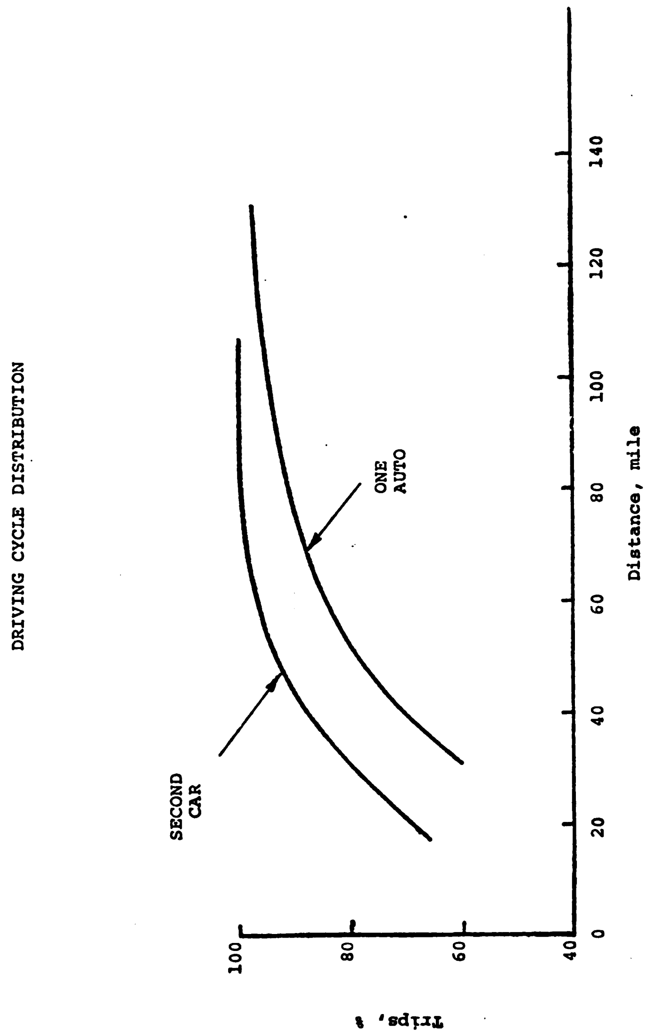
Finally a synthetic fuel route via nuclear power is considered. Such processes involving hydrogen followed by perhaps ammonia production are very unattractive on an energy basis and quite speculative.

In each of these three cases the battery powered electric vehicle is more efficient because of the high efficiencies of secondary batteries and the high efficiency of electric motors and the relatively high and improving efficiency of central stations.

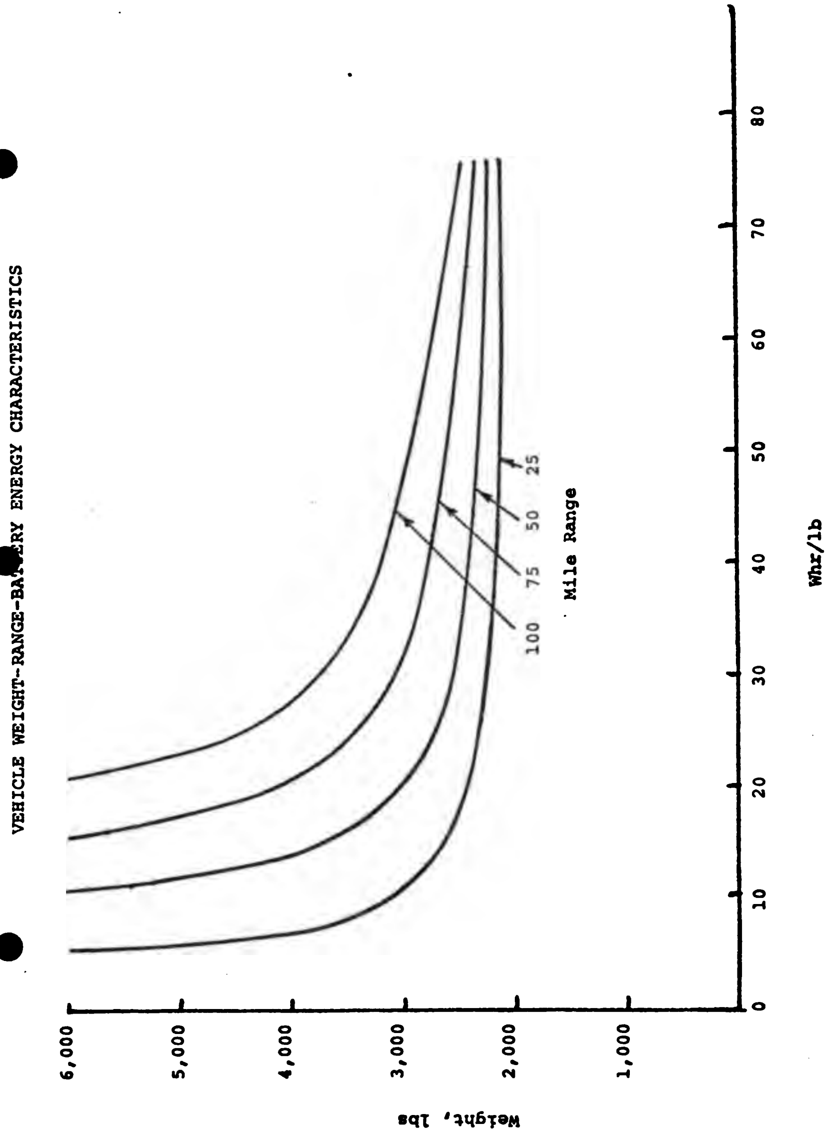
BATTERY SELECTION

If one accepts the electric vehicle as an attractive concept on an energy basis, the next question to be asked and answered is the type of battery r

Actually battery selection itself has two parts. First, is the definition of the application and next is the choice of technology to meet the requirements. A reasonable first generation electric vehicle should take the form of a modest size passenger car, probably a second car, or a small delivery truck. A recent analysis of American driving profiles is quite revealing. It has shown that 80% of first car trips and 95% of second car trips are under 60 miles per day (Chart



2). If battery selection is directed at meeting this range requirement, it is apparent that a 30 Whr/lb. battery is sufficient. The effect of battery energy density on range requirements is shown in Chart 3. Clearly, a battery with high energy density only marginally expands the market in which the electric vehicle can participate. Lower energy densities begin to reduce the marketability, but even here, there are substantial market possibilities at lower energy densities.



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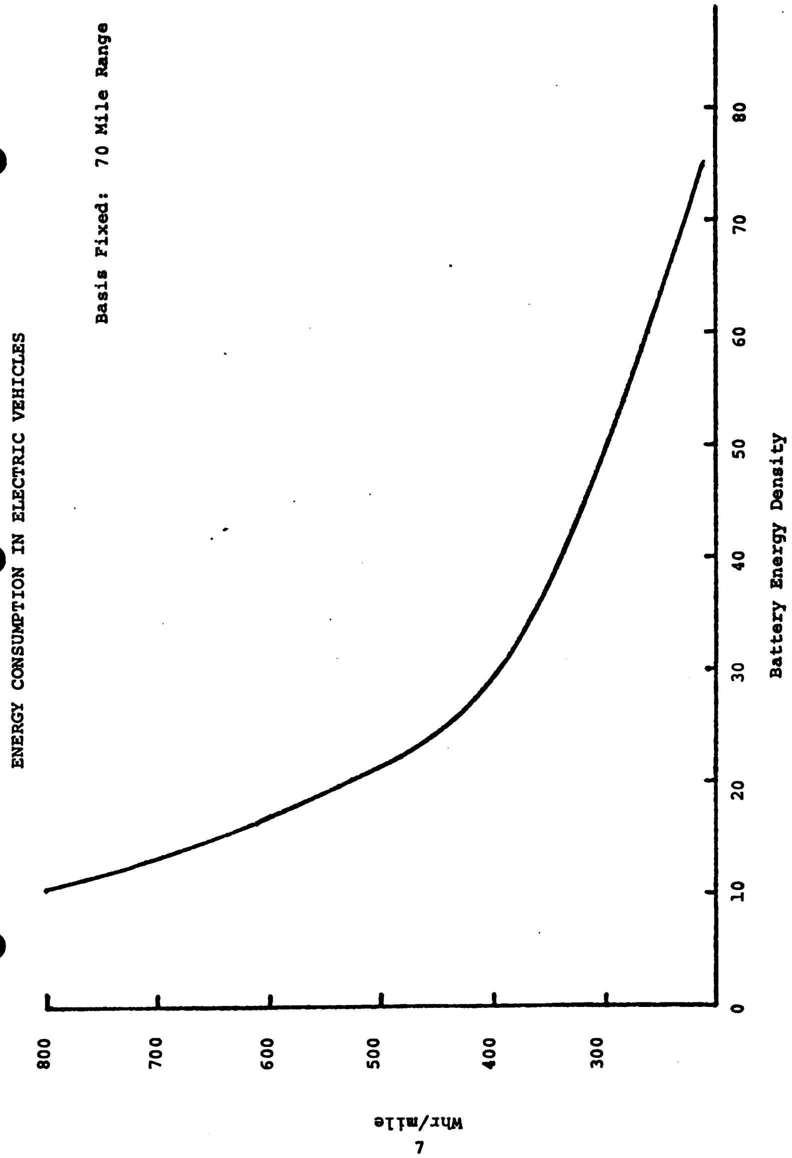
The battery energy density does, of course, impact the energy required per mile of driving. This is clearly shown in Chart 4. The reason for the sharp rise in energy per mile at the low range of energy density is that in this range much of the energy is being spent in moving batteries rather than payload.



This is shown in another way in Chart 5 for small trucks where battery weight and payload is shown as a function of battery energy density.

At the low energy end the extra battery weight begins also to cut into range. In Table 1 a nickel-zinc battery in the 30 Whr/lb range is compared with a 12 Whr/lb lead-acid battery for a modest size passenger vehicle. The comparison dramatically shows the substantial vehicle improvement by the use of nickel-zinc batteries.

PAYLOAD - BATTERY ENERGY CHARACTERISTICS

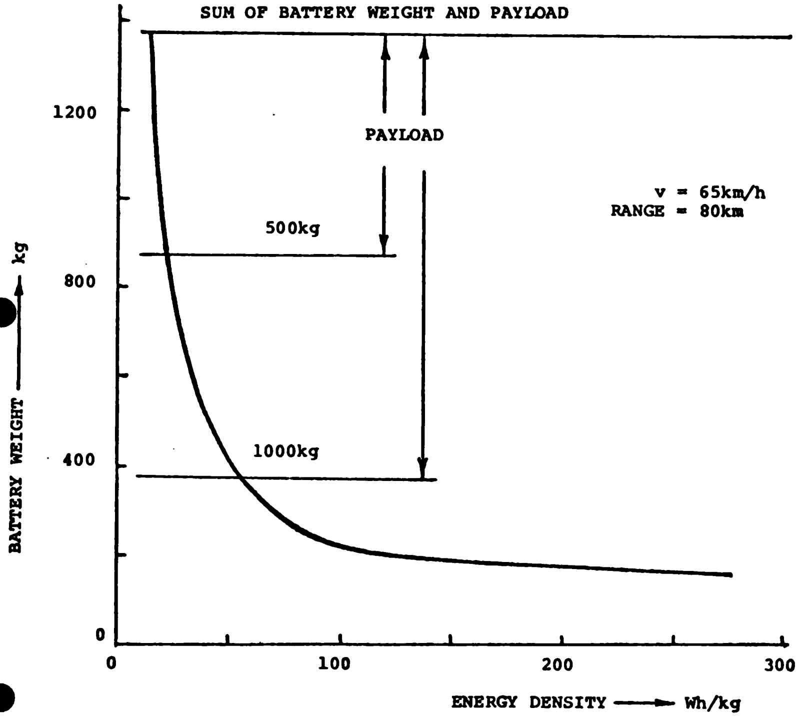


TABLE I.—VEHICLE CHARACTERISTICS

Comparison basis	Range in miles	Battery weight in pounds	Battery energy in killowatt/hours	Curb weight in pounds	Discharge—Energy out/mile (watt-hour/mile)	Charge—Energy in/mile (watthour/mile)
Range Pb-Acid	70	4,740	57	7,400	810	1,100
Range Ni-Zn	70	670	20	2,500	285	385
Energy Pb-Acid	44	1,670	20	3,700	450	610
Energy Ni-Zn	70	670	20	2,500	285	385
Battery Weight Pb-Acid	27	670	8	2,500	285	385
Battery Weight Ni-Zn	70	670	20	2,500	285	385

The choice of a battery for electric traction requires a balance between economics and energy density. The highest energy density secondary batteries available today are silver-zinc with an energy density of about 45 Whr/lb. Clearly such batteries which cost about $1/Whr are far too expensive. The lead-acid battery which sells for 2 to 10¢/Whr is too heavy. The nickel-cadmium battery about 50% more energetic than the lead-acid battery is also quite expensive costing at least 40¢/Whr. No commercial battery on the market today is suitable for electric traction.

Many new battery systems are under investigation. High temperature ba
are unsuitable for traction. The zinc-Chlorine and nickel-iron systems

complex impractical systems with low overall energy densities. Zinc-air and zinc-oxygen systems are potentially interesting but are still complex hybrids of fuel cell and battery technology.

Only the nickel-oxide zinc battery represents a reasonable battery choice for widespread traction applications in the forseeable future.

Energy Research Corporation has been developing this battery for the last five years and considerable progress toward the realization of traction battery technology has been made. Unique in the ERC nickel-zinc battery technology is a greatly improved zinc anode, low cost non-sintered nickel cathode and stable long life inorganic separator. The components can be made into a 30 to 35 Whr/lb battery with reasonable economics. A comparison between ICE & EV Costs are shown in Table 2.

At this point in time much experimental work has been focused on small batteries. It is now time to initiate the development and engineering programs required to bring this nickel oxide-zinc technology to a complete traction battery system.

TABLE 2.—COMPARISONS OF ICE AND EV COSTS

	ICE				EV							
Initial vehicle cost		$3,000						$3,000				
Vehicle life (years)		10						15				
Initial battery cost								$1,000				
Battery Life (cycles)						500					1,000	
Depreciation vehicle cents per mile						2.0					2.0	
Depreciation battery cents per mile						2.8					1.4	
Fuel costs cents per gallon cents per kilowatt	0.55	0.65	0.75	1.00	2.0	3.0	4.0	5.0	2.0	3.0	4.0	5.0
Cents per mile	2.7	3.2	3.7	5	.8	1.2	1.5	2.0	.8	1.2	1.5	2.0
Oil cents per mile	.1	.1	.2	.2								
Use tax cents per mile					.4	.4	.4	.4	.4	.4	.4	.4
Repair and maintenance	2.4	2.4	2.4	2.4	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2
Total cents per mile	8.2	8.7	9.3	10.6	7.2	......	7.9	8.4	5.8	6.2	6.5	7.0

It is our opinion that a reasonable performance modest cost electric vehicle could be developed and field tested based on the nickel zinc battery within the next five years. Substantial numbers of nickel zinc powered electric vehicles, 1,000,000 per year, could be operating on American highways within the next 8 years.

Senator Moss. We will now have a panel that will appear together at the table, Mr. Robert G. Beaumont, president and chairman of the board of Sebring Vanguard; Mr. James Norberg, administrator of the electric vehicle program of that company, and Mr. Leon Shahnasarian, president of Elcar.

Could those gentlemen come forward, please?

We are pleased to have you. You represent what, I suppose, are the principal electric vehicle manufacturing companies, and you should be able to bring us information that we need for our record.

I will ask you to submit whatever written statements you have, and request that you proceed as best you can, to summarize, due to our time constraints.

Mr. Beaumont will go first.

STATEMENT OF ROBERT G. BEAUMONT, PRESIDENT AND CHAIRMAN OF THE BOARD, SEBRING VANGUARD, INC.; ACCOMPANIED BY JAMES NORBERG, ADMINISTRATOR, ELECTRIC VEHICLE PROGRAMS

Mr. Beaumont. Thank you.

I understand there are two newspapers in Washington; one is the

Washington Post and I hesitate to mention the name, but I believe, the Washington Star.

On Tuesday, September 23, on page 2 of the little paper I prepared—the heading says, "A not-so-daffy little car." It says, "Our critical oil difficulties mandate a variety of searches for energy alternatives. The vision of our purring around the city someday in little electric autos, emitting no air pollution and no noise anyone would notice, is not to be joshed away."

I have prepared a little booklet. I hope you all will read it, which says not only what we say about the electric vehicle, but quotes from dozens of people across the country who are using the cars, and who are expressing their opinion as to the future of electric vehicles.

To address specifically to the four points you brought up at the beginning of the meeting, one of the present performance characteristics of electric vehicles is a 35-to-40-mile-an-hour top speed in a 35-to-40-mile range.

This present performance characteristic of these cars presently will handle a percentage of approximately 83 percent of urban travel. So it is not a question of what the electric car can't do. I think we should concentrate on what the electric car can do.

If that percentage of vehicles is used as urban commuters, are of that magnitude, then we have to get started, obviously, on the development of vehicles. As far as energy usage, soon there will be a new terminology to recognize mileage on electric vehicles.

It will be how many miles per K, how many miles per kilowatt-hour. Presently we have tests that show our vehicles can go approximately 4 miles per K, or 4 miles per kilowatt-hour. So to determine the efficiency and economy simply take the local kilowatt-hour rate and divide by 4.

Case in point, if it is 4 cents a kilowatt-hour, and you go 4 miles per K, it is 1 cent a mile. Obviously in New York City where it is double that, it costs 2 cents a mile.

So the terminology, how many miles per K, I think you will be hearing more of.

The second point was probable improvements that may come as a result of this bill. Obviously trial and error is something that has gone on since the days of Henry Ford. It is the same thing we are going through right now and I am sure Elcar is.

In the past year we have got dozens and dozens of improvements that have been instituted into the production line and these cars go out in the field to dealers and hence to customers.

I know for a fact Elcar has dozens of improvements that have been put into their vehicles in the past 18 months. So only through trial and error and through a chance to survive in a market, which we think exists already, will product improvement take place, because if you take this to the laboratory, such as Professor Haywood suggests, it is decades and eons before something comes out of the laboratory.

You need hundreds of millions of dollars of R. & D. which result in a paper for your perusal, but very little hardware. As far as institutional barriers are concerned, there are many.

Take the latest Consumers Union Report, which you mentioned before. On the next to last page of the little booklet I prepared, one particular person issued a press release in connection with the Consumers Union Report.

If you could look at the very last article, the very last paragraph of that report of Mr. Charles MacArthur, it says, "Recently MacArthur purchased a dozen eggs and took them to his testing laboratory. He dropped each egg very carefully from a height of 2 meters onto a concrete floor. 100 percent of the eggs tested broke on impact. As a result, he has forbidden the purchase of any more eggs until the chickens develop a more crashproof egg."

This typifies the somewhat national mania of safety. It typifies what Consumer Union is concerned with, and what price safety, or what comparisons with the egg situation. We have been banned from Michigan, Senator Moss. This happened recently.

All 50 States were licensing the little CitiCar until a State trooper in Michigan tested the car and decided unilaterally that the plastic body wasn't safe. Therefore, the car was banned in Michigan.

Currently, we have about 15 dealers in the State of Michigan with about 50 cars on hand that they don't know what to do with them. This is an institutional barrier.

All your advertising is based on sex symbols. It permeates society as to the importance of owning a gushy looking automobile. Indeed, even the Congress was skeptical when this bill was first introduced—until the Congress began to think, until the Congress had time to analyze the points brought up by Mike McCormack and the other members who voted almost unanimously on the bill. Once the thinking took place, you people realized the parameters within most of the nations, fall within the present characteristics of cars.

We need orders so we can plan production, so we can buy merchandise, so we can get out supplies to gear up and make these cars available.

Senator Buckley brought up a point before about the Government agencies purchasing these cars. This last week in a 2½ hour meeting at Fort Gordon near Augusta, Ga., one of our transportation specialists had a long meeting with the transportation people at Fort Gordon.

Out of the meeting came a report that is on its way to GSA now, that of all the vehicles owned by the Federal Government on Fort Gordon right this moment, 61 CitiCars take the place of 61 conventional vehicles, which would mean an enormous saving of money and energy at that particular site.

As far as batteries are concerned, in my opinion, at least 10 percent of the funding in this bill should go toward battery development, because as Dr. Baker said, this is the key to a vast potential market for electric vehicles. The battery R. & D. should not be overlooked.

Basically, that is my summation of the four points that I feel are important.

Thank you.

Senator Moss. Thank you, Mr. Beaumont.

On the car that you produce now, how large a battery is available for that car?

Mr. Beaumont. Total battery charge, 6, 8-volt batteries. These propel our vehicles at 38 miles per hour for a range up to 50 miles under identical conditions.

The true mileage you can expect in this vehicle is a solid 40 miles. Above that, you are doing well, unless you have excellent tem-

perature and terrain. We get many reports from the field that people will commute 27 miles one way to work; they will plug in for a couple of hours, and they easily make it home.

There are many instances of 55 and 60 miles per day put on our vehicles by a few hours' charge while the car is parked.

Senator Moss. How long have you been producing your car?

Mr. BEAUMONT. Four years ago, Senator Buckley helped my company very much when we were in New York developing the concept. He helped us with the National Highway Safety Administration and some of the other Government agencies who weren't quite sure how to classify this car.

So my own involvement has been 8 years, as far as electric vehicles are concerned. I formed the company in May of 1973 in Sebring, Fla. We spent a year for engineering, tooling, designing; we went into production in May of 1974.

At this point, we have produced 1,570 cars, 1,500 vehicles are out in the hands of dealers, and about half of those are in the hands of consumers.

I might say that my company in the 2 years we were in existence, first year for development and second year for actual sales; we took a total of almost $1 million invested in private capital to get to this point.

One of the reasons we must advocate and support this bill, there is always the chance that the work we have done could go "belly up" like what happened recently to Mr. Burton in Canada. That took $22 million before he went under.

We believe this vehicle can perform a function in the Nation's transportation, and we think Congress should pass this bill and give some assistance, whether in the form of loan or capital, to continue the work we already started.

Senator Moss. I may have some additional questions if time will permit. I would like to turn to Mr. Shahnasarian. We would be pleased to hear from you and, if any of the other gentlemen have any statements they would like to make, we would turn to them next.

STATEMENT OF LEON SHAHNASARIAN, PRESIDENT, ELCAR CORP., ELKHART, IND.; ACCOMPANIED BY ROBERT CULVER, TECHNICAL DIRECTOR; AND PETER GREENBERG

Mr. SHAHNASARIAN. Mr. Chairman, my name is Leon Shahnasarian. And I am president of the Elcar Corporation. The two gentlemen on my left: Mr. Peter Greenberg, who is our representative here and handles government relations, and Mr. Bob Culver, vice president in our company.

Senator Moss. It is very good to have you.

Mr. SHAHNASARIAN. They are well-qualified people to answer questions. I won't read the whole testimony but I would like to read just one section of it.

The Elcar Corp. already has available a very capable, basic two-passenger electric car. Due to our past experience and to the tremendous interest seen in these diversified means of transportation, we, the Elcar Corp., are presently in the process of tooling up for the manu-

facture of our own American version of an electric van-style vehicle. This vehicle will accommodate four passengers, can be used for light delivery service, is ideal for governmental agencies, and could be made to comply with postal delivery requirements. With sufficient financial support, we could conceivably mass produce these vehicles in approximately 6 months. Mass production would result in cost savings which could allow competitive pricing in relation to the conventional gas-driven automobile.

Senator Moss. That is fine. I appreciate it. Of course, the entire statement goes in the record. We are very glad to have it.

Mr. Culver. We would like an opportunity to proceed with your questions and answers that I am sure our panel discussion is to bring out.

Senator Moss. All Right. We will proceed with that. Some of these questions may require a response from more than one of you.

First of all, it was mentioned by Mr. Beaumont that they had some institutional impediments in Michigan. What have been the major problems in trying to get your vehicles on the market? Maybe each one of you could try that.

Mr. Beaumont. Institutionalwise it took us 2½ years to get through New York State. They wanted certain things in the car they felt were necessary to protect the safety of the citizens of New York. We finally complied with all the New York State requirements and are licensable there.

The State of California originally licensed the vehicle, but the rather large bureaucracy there found that certain of the lights on the vehicle were not in absolute conformance with California regulations. While they were in conformance with Federal regulations, that didn't matter. So, as a result, we changed our lighting to conform to California regulations, and, in effect we went standard on those lights, so they not only conform with California but the Federal Government as well.

With the exception of those two States we have had very little difficulty getting the cars licensed in most areas. This Michigan fiasco took place—my stockholders, many customers, dealers—dealers blame this a lot on Detroit. OK? I don't. I can't conceive of any pressure coming from the "motor moguls" in Detroit that would have an effect on banning the electric car in Michigan.

However, it seems strange, I must admit, that is currently the only State in the Union that will not license the vehicle. I think it is just a bureaucratic snafu. I hope it is. We are going to the courts with our limited resources to try and get injunction against this unilateral decision by one State trooper, whose main reason was, he feels the plastic body on the vehicle is not safe. I mean, that is the whole basis of it being banned in Boston—I mean banned in Michigan.

Senator Moss. What problems do you encounter with your vehicle?

Mr. Culver. The largest single problem we had, especially with our earlier models, was speed. As an institutional matter, we have run into some State problems which we have solved now, but basically—but our early opposition was the fact that our vehicles blocked the highways. It quickly developed, we noticed the State motor vehicle administration in the various States refused to segregate or separate our car from other cars.

Now, our car, as you have heard, such as in all the testimony you heard today, we don't recommend that anybody sell a family car and buy one of these. It is a second car. It has its place in neighborhoods, downtown and what not.

The State of Maryland was originally very concerned that we would get out there on the Beltway or something at 6:30 in the morning and here would be Elcars, and city cars abreast of it and everybody else backed up 30 miles. Well, the vehicle has no place in or on the Beltway per se. We acknowledge that as much as anybody else. The fact is, certain State motor vehicle—perhaps, the States will have to progress to the point of classifying roads on which these things may or may not operate, depending upon their performance characteristics, as the vehicles improve, and they will improve.

Maybe the classification will become an anachronism, then we will have to fight to get them taken off. As of now, I don't think we should be banned totally from anywhere, because there are places, just because there are certain places such as the Interstate Highway System on which we are not ready to enter that yet.

Senator Moss. Well, if an Interstate Highway has a 45-mile minimum, and a 55-mile maximum, are you stating that you shouldn't take one of your cars onto such a highway?

Mr. Culver. That is correct. Our problem initially in some States, we were having a rough time licensing our vehicles there because they wouldn't meet these minimum standards for certain state roads. You must remember other States have good roads also. They are not part of the Federal Interstate Highway System, that are up to a par with the Federal system. The States had no method or no regulation for saying you have a car to operate here but not there. You either have a car or you don't have a car.

Therefore, it was difficult for them to contend with our vehicle. This may also affect the safety aspect, as well as the flow of traffic. We don't need to worry about high-speed impacts, if our vehicles are permitted on only roads with a speed limit of not less than such and such or more than such and such.

Senator Moss. Do you have any idea of approximately how many of your cars are now operating on the road?

Mr. Greenberg. Well, we have less than a thousand, Mr. Moss, on the road at this time. Our program is a year newer in its infancy than Mr. Beaumont's itself.

Senator Moss. Is it about 1,000 or considerably less than 1,000?

Mr. Greenberg. Considerably less than 1,000.

Senator Moss. For that reason, would you support the part of the bill requiring the buying of more demonstration cars so that you could have some assurance of a market and begin to manufacture?

Mr. Greenberg. We would express ourselves the same as Mr. Beaumont did. We need that assurance of procurement as well as we need the funding for a new enterprise such as ourself. Previously, it is well known we have an imported vehicle, which is basically a two-passenger vehicle. We know the market is there for our van-style vehicle. We feel now the public is ready to accept this. We have all done a whole lot of work as well as Mr. Beaumont has in introducing the concept of the electric vehicle to the public. We are more than confident the public is ready to accept it.

We don't need an exotic battery to start out. You have primarily basic needs of transportation. We find the whole existing problem lies in the association of our electrics with a conventional gasoline-driven automobile. We have to do our best to show the people the value and the need of these electric cars, and not to be going from here to California, or vice-versa, et cetera.

Just plain basic transportation needs.

Lead-acid batteries, I believe Mr. Beaumont will agree, offers that right now. We have a viable product for what it is intended for.

Senator Moss. Do you presently have any exemption or dispensation from Federal safety standards?

Mr. Greenberg. Yes; we do, Mr. Moss. We have, for one thing, the heater-defroster exemption on the vehicle. An electric vehicle does not lend itself to a high drainage of ampere, which is required from a good heater and defroster unit. We do, as well as Mr. Beaumont, have alternate means of supplying the heater and defrosters at this time. But as to the aspect whether they will satisfy safety standards, that is another question.

Another item that we don't feature, and I am not sure if Bob does in his, is the key alarm, where if you leave your key in your ignition, you will have an alarm system. We haven't finished our engineering on that, as to how to accomplish that.

Third, we have the situation—the 2,500-pound minimum. Modern-day cars have a very heavy, elaborate engine on the vehicle. In the structure of our cars there has been nothing designed to compensate for that. That again is going back into your high-impact-crash requirements of the vehicles.

Other than that we feel we can comply with all of the safety standards.

Mr. Beaumont. Senator, I think what you are trying to get at possibly—let me really speak for the record and make it really clear. The Federal Government, as far as the DOT is concerned—and in particular, the NHTSA which determines Federal regulations—has been extremely cooperative and very friendly to our efforts to get these electric commuter vehicles on the road. As far as I am concerned, they have gone out of their way to give us what sensible exemptions are required. I think that attitude goes—argues well for greater acceptance of limited speed and range. That is an important function.

Senator Moss. Will it be necessary to have continuing dispensations or ultimately will you be able to comply with all safety regulations?

Mr. Beaumont. The Department has long thought about writing regulations for low-speed limited-range lightweight vehicles. I believe when industry and the NHTSA have the time to sit down together and work these problems out, I believe electric vehicles can comply with all applicable Federal regulations. Yes; I think that can work out.

Mr. Greenberg. We would agree with Mr. Beaumont that it all can be worked out.

Senator Moss. That is a very hopeful note.

I appreciate your coming. You are the people that are making and marketing the vehicles we are talking about. For that reason we are most pleased to have you come before the committee in order to pro-

vide us this important data. We thank you very much, and if we have additional questions that occur to us, we will send them to you in writing.

Mr. CULVER. Senator Moss, I wonder if you might hear us on one point that hasn't been mentioned so far today. I will be very brief as we have been so far.

Senator MOSS. All right.

Mr. CULVER. H.R. 8800 contains a provision for loan guarantees for the development, production, and manufacture of these vehicles, as well as certain research. S. 1632 does not. We would hope that S. 1632 will be amended to conform to H.R. 8800. As the Senator knows, I am sure, H.R. 8800 started life very much as S. 1632 appears today, but there are several differences in it. A major one is that S. 1632 does not as yet contain that loan guarantee provision. In order to put these vehicles on the road, H.R. 8800 represents a very balanced effort. We have to develop the market and the vehicle. The supply and demand have to keep pace with each other. All of us can make it just fine producing a few vehicles for a limited market.

The demonstration program hopefully will expand our market. The loan provision will enable us and others to follow on to commence the production of these vehicles. It is as important as any other factor. Certainly we have already heard what the bankers think of this from some other witnesses. This is not a conservative investment for a banker to make in the form of loan capital.

By the same token, the state of the stock market notwithstanding, it certainly is not necessarily a good investment yet on the stock market. We certainly wouldn't recommend a widow or orphan to put his savings or trust fund in the stock of this company. This is just the kind of new venture that requires Government assistance and hopefully if we have it now, we won't have to be coming back here in 3 years and then in 6 years and then in 9 years and say, "We need a little more help."

Certainly, this is one of the fears this committee must face and we would like to be able to get over it. We need to be able to stand on our feet so we can go out and say, "We have a viable product. We have worked out all the problems and we are going to sell this to the public and the public is going to buy it in accordance with the free enterprise system without subsidy from the Government."

Now is the time to give us the help, when it will do the country some good and do us some good and we would hope the loan provisions, which would finance that—it is just loan guarantees, it is not costing the Government a dime—would be incorporated in H.R. 8800. We hope the Senate will pass H.R. 8800 as written.

I asked Mr. McCormack why he called this a $160 million bill. As it is to be administered, it isn't. It won't cost the Government that much. The cars the Government buys under this bill, if the Government uses them, will be cars both from the conventional manufacturers anyway, if they choose to disseminate them and put them in the hands of the public. If the Government buys them, uses them, they will remain a curiosity. We are anxious to get outside the category of being a curiosity. We want to see them in driveways around the country. If they are disseminated in such a fashion, presumably

ERDA, through us or whatever they settle, will sell them and recoup a substantial portion of the purchase price. There is a lot that wouldn't be recouped, the setting up of the lines to put them out.

The second thing is, the $60 million for the loan guarantees, hopefully there will not be very many defaults and the Government wouldn't be called upon to ante up the money to pay for these guarantees.

So, the cost to the Government should be far below or just a small portion of the $160 million for it.

Senator Moss. Thank you for your comments on that. We will consider them very carefully when we look at our bill.

Thank you, gentlemen, we appreciate your coming.

[The statement follows:]

STATEMENT OF LEON G. SHAHNASARIAN, PRESIDENT, ELCAR CORP.

Mr. Chairman, as President of the Elcar Corporation, I and my accompanying associate, Mr. Robert L. Culver, appreciate this opportunity to appear before this Committee to express our views on the proposed Electrical Vehicle Research, Development and Demonstration Act.

The Elcar Corporation, an Indiana Corporation, has actively been engaged primarily in market research and consumer dealer development for the past 18 months to determine the actual need and public acceptance of a diversified means of transportation offered by an electric passenger car.

We cannot ignore the realization of barriers confronting us in technological and economic development, although we do know that we, the Elcar Corporation, and Sebring-Vanguard already have a viable commuter passenger car that fits the majority of today's transportation needs.

The electrical vehicle popularity had reached its peak in the early part of this century. If we had the foresight and had continued the electrical-powered automobile research and development, an earned share of the automobile market of today would have been in electric automobiles and trucks and would have considerably lessened the amount of crude oil already consumed. However, it is never too late to begin the development of alternate means of transportation.

The Elcar Corporation already has available a very capable, basic two-passenger electric car. Due to our past experience and to the tremendous interest seen in these diversified means of transportation, we, the Elcar Corporation, are presently in the process of tooling up for the manufacture of our own American version of an electric van-style vehicle. This vehicle will accommodate four passengers, can be used for light delivery service, is ideal for Governmental agencies, and could be made to comply with postal delivery requirements. With sufficient financial support, we could conceivably mass produce these vehicles in approximately six months. Mass production would result in cost savings which could allow competitive pricing in relation to the conventional gas-driven automobile.

I, myself, and the Elcar Corporation sincerely wish to commend Mr. Moss, Mr. Humphrey, and other supporters of S. 1632 for the introduction of this bill.

The contents of proposed S. 1632 are of utmost importance in the introduction of electric cars. It is designed to assist in the research and development of improved battery technology and also to encourage the smaller independent manufacturers like ourselves. With a certain amount of financial assistance and actual vehicle procurement commitment, it would be a certainty that our program could move rapidly ahead. We, being a privately capitalized corporation, have already invested a considerable amount of capital in our development. If the House and Senate do determine the availability of funds for this purpose, we would welcome ERDA funding to assist us in completing our development work to produce the multi-purpose commuter vehicles in sufficient quantities to satisfy Government evaluation and actual consumer usage.

We extend our full support to the passage of this legislation and offer any assistance that we can provide. Too, we appreciate the look-to-the-future attitude seen in this legislation that will open the eyes of our countrymen to the diminishing oil resources and the environmental conditions of today.

We feel the need to begin preventative corrective measures is now, and we ould not allow several lost years to slip by before a preventative program is tiated.

Again, we wish to thank you for this opportunity to comment and lend our support on this bill.

Senator Moss. I would now like to have Mr. Forbes Crawford, president of Jet Industries and Mr. Spencer R. J. Cox, chairman of the board for Unique Mobility come to the table.

We are pleased to have you before the committee and look forward to your testimony. As I said before, the statement will be placed in the record in full. We will ask you to highlight and emphasize the parts of your statement that you particularly would like to bring to our attention.

Mr. Crawford, would you care to go first?

STATEMENT OF A. FORBES CRAWFORD, PRESIDENT, JET INDUSTRIES, LTD., NEW YORK, N.Y.

Mr. Crawford. Thank you, Senator Moss.

I would like to do this sort of backwards, because of the last statement made by the previous witnesses. They were emphasizing the necessity of loan guarantees. I have an article here, which I am going to leave with the committee, out of Business Week for September 22, 1975, which states that there is a tremendous shortage of capital and will be in the future, and that small businessmen will have a difficult time surviving under the serious capital position.

A number of months ago in New York City when I contacted brokers with whom I had done business before, their response was, why should we put money—our customers' money—in a new business, new industry when we can get them into going businesses at a discount on the New York Stock Exchange or American Exchange at one or two times the earnings?

Some of those bargains are still available. Since the June House hearings, we had a bank in New York agree to participate in an SBA guaranteed loan of their maximum of $350,000, if banks in our manufacturing city of Seattle, Wash. would handle the mechanics of it and take a small part of it.

None of the banks in Seattle would take it because they didn't know where the additional $1 million which we would probably need in the ensuing 12 months was coming from. Therefore, the important thing is, even though the Government may guarantee 90 percent of the loans for electric vehicle companies, the money may not be available because banks and other lending institutions will have priorities with their biggest customers. And banks might violate their Federal Reserve requirements by making even an additional Government-guaranteed loan.

The Business Week magazine—it's a special issue by the way—also emphasize that the banks and financial institutions will give preference to their larger and older borrowers. So I made a recommendation in my written statement that the administrator of whatever bill results, may make direct loans to manufacturers of electric and hybrid vehicles if they are going to finance those, and to qualify for such loans, the manufacturer must have produced a prototype which can meet pre-1966 NHT safety standards, prevailing in the State in which the manufacturer resides.

This would be in addition to the normal loan requirements such as access to facilities, management, and production abilities. Such loans

could be handled by already existing SBA offices on such formulas as may be developed by the administrator of the electric vehicle bill.

In No. 6 on page 5 of my statement, I say as an alternative to the loans, the administrator may be authorized to make progress payments to manufacturers of electric vehicles purchased by the U.S. Government up to 75 percent of the purchase price and 10 percent more on delivery, being allowed a 15-percent discount for having paid in full before delivered. This is made because, again in a tight money situation, a borrower might not be able to borrow on a U.S. Government account receivable.

Now, a precedent for this suggestion is the fact that, I don't know whether it is the Department of Transportation, but it may be, are financing 80 percent of the Metropolitan Bus acquisitions.

The foregoing, of course, falls in with the provision of H.R. 8800 for purchasing vehicles. Those are the major considerations that I think the Senate should have in their bill, by having direct money available to qualified manufacturers of electric vehicles.

Now, the other thing which I recommended is that, to accelerate the production of electric vehicles, that manufacturers be required to conform only with individual State licensing requirements prior to 1966 NHTSA safety standards.

The reason I am suggesting that is, that although we are starting out with a small van which we import and convert to electric battery power, and which, but a few exceptions can meet NHTSA commercial safety standards, it does not comply with passenger standards. If there is a vehicle on which a foreign manufacturer of the chassis and body has spent many millions of dollars developing it, producing it, and have had years of experience doing it and that vehicle does meet the safety requirements in the country of origin, the manufacturer will not change for a limited number of vehicles for electric conversion. It is the vehicle which is shown on the picture on the front of my presentation here.

[Picture follows:]

I would like to add one thing to what the previous witnesses said. That is the Citicar and Elcar are identical types of vehicles for commuting between homes and offices and businesses in smaller communities where the distance isn't too far where your normal speeds aren't very high. You take, for example, in New York City, you could probably run a CitiCar at a normal traffic speed across town with a couple of flashlight batteries.

In other words, that is what happens in your bigger cities. You just don't need a lot of speed. So they are no hindrance to traffic.

Another point I would like to bring out, which hasn't been brought out, that is there is the big problem in the big cities—and you may not see the development of the electric vehicle in the big cities—because of the high cost of the garages. Many of the places that have garages don't have electricity available for charging the batteries. If you had meters in big cities you would have a musical-chair situation every day, people trying to find a place to park and you would be competing with the internal combustion engines and where they have an alternate-side-of-the-street parking, there would be the same kind of thing going.

In our own particular instance in three different cities where we have offices, we have problems finding places in executive's apartments to charge our batteries, so to speak.

Senator Moss. Well, thank you, Mr. Crawford. Your full statement and the attachments you have made to it will be part of our record. I do appreciate it. I am going to have to postpone questions.

In fact, those telephone calls I just received are telling me I have to go to the floor. I will ask counsel if he will stay and complete the testimony of Mr. Cox and then we will submit written questions, if there are gaps we want to have filled in or things that occur to us.

I recall going over and seeing your car when it was parked over on the House side, and we are very appreciative of having you come here as well as having Mr. Cox come to give us the benefit of this information.

You point out that the problem of getting financing is pretty difficult in a new or untried area, and therefore, you would like direct loans authorized?

Is that right?

Mr. Crawford. This is not only true of new and untried business but any small businesses.

Senator Moss. Thank you. I apologize, I must leave early. So we will carry on and adjourn the hearing when you get finished.

[The statement and attachments follow:]

STATEMENT OF A. FORBES CRAWFORD, PRESIDENT, JET INDUSTRIES, LTD.

ULTIMATE ELECTRIC VEHICLE

Mr. Chairman and Gentlemen, the Commerce Department of a large University was asked to make a feasibility study of Electric vehicle potential. The staff first of all made an analysis of commercial vehicle use—that is—daily mileage and so on—with large representative samples of commercial vehicle users in a metropolitan area. And the second thing they did was a fairly complex study of commercial purchaser preference and basically concluded that:

Electric vehicles that were available were lacking in two respects:

1. The high first cost.
2. The limited range.

The analysis showed that if either one of these factors and not necessarily both of them, could be significantly improved—that is, if the price could be brought down or if the range were increased there would be a very significant market immediately.

The study was made without knowledge of our vehicle's performance and price. When the utility company that had asked for the study, acquainted themselves with our vehicle they placed an order for what I believe is the largest number of electric vehicles of one make bought by any utility company in North America—five to be exact.

Our main production vehicle goes 45 mph and 100 miles per battery charge. The retail price is $4,800. It is a light delivery or service vehicle which can be used as a small station wagon carrying three passengers besides the driver.

The following comparative figures were taken from various publications on Electric vehicles:

ELECTRIC VEHICLE STATISTICS

	Manufacturer			
	Battronic	Otis	AMC [1]	JET
Miles per hour	30	45	33	45
Miles per battery charge	40	50	20	100
Volts	112	96		84
Weight (pounds)	6,000	3,800	3,690	1,934
Payload	1,000	500	700	700
Wheelbase (inches)	94.5	96	81	68.2
Overall length (inches)	145	138	136	117
Overall width (inches)	78	65	70.72	51
Cargo space (cubic feet)	140	70	50	90
Retail price	$16,330	$8,500	$5,598	[2] $4,100–4,800

[1] American Motors Jeep.
[2] Lowest price is for MINITRUK—highest for ELECTRA VAN.

The EVI sold 50 units of Battronic Vehicles to Public Utilities for testing.

I recommend that Congress should set performance standards similar to ours: 45 mph—100 miles to a battery charge, for vehicles not exceeding 2,000 lbs. weight with batteries and various other standards for different weight & payload characteristics.

Japan's Industrial, Science and Technology Agency has earmarked $10 million for a five-year program. An agency spokesman says the first performance goals, a speed of 50 mph. and a range of 124 miles between charges, were "completely achieved" and improvements are under way.

The Argonne National Laboratory in the U.S. estimates in the longer term that there could be as many as 1.8 million electrical vehicles on U.S. roads by the year 2000, requiring only 0.9% of the electricity generated in the U.S. The laboratory thinks that within five years a battery five times more powerful than the current lead battery will be on the market, giving a 100-mile no-recharge radius to the small electrical vehicle, which compares favorably with some small gasoline-fueled cars now marketed.

Now I would like to tell you how we arrived at our performance figures:

Myself and my partner W. L. Bales have been associated with the electric battery and I/C-powered small vehicle business, probably as long as anyone present.

In addition, as individuals (and I'm not speaking of corporations) we probably have more of our own money invested in electric vehicle development than anyone present.

Many of you may know that many years ago when Ford Motor Co. decided to become interested in automobile racing, spending millions of dollars through their engineering staffs without the success they had hoped to attain. The company made a deal with one of the best "Cut and Fit" engineers in the race car business, Carroll Shelby. From then on Ford was very successful in the race field.

I like to think that, my partner, Bill Bales, is to The Electric Vehicle business as Carroll Shelby was to the race car business in the U.S.

Mr. Bales manufactured many thousand of 3 and 4 wheel golf cart and indust l Electric Vehicles in the late 1950's and early 1960's until a large company t his company out.

He had experimented and worked with many different innovations that have been and are being tried in the Electric vehicle field.

1. Electric motors on each rear wheel.
2. Combination of Internal Combustion and electric battery powered drive.
3 Converting conventional American Trucks to Electric Battery Power.
4. Converting conventional American Automobiles to Electric Battery Power.

In the early 1960's we recognized a need for conserving fossil fuel and were partners in a small private truck manufacturing company that had developed a small American-made gasoline-powered vehicle to fill the market subsequently filled by only foreign-made gasoline-powered vehicles—Datsun, Toyota, Mazda, Ford Courier and Chevrolet LUV pickups.

In the late sixties we were developing an electric powered version of the aforementioned small van. It does perform along with the average of similar vehicles now on the market: 30 mph—50 miles per charge.

However, even before the energy crisis of 1973 we believed that it was necessary to develop a performance of 50 miles per hour and 100 miles per charge to have a commercially acceptable vehicle.

Fifteen years ago we had previously been through the exercise of using golf cart components—suspensions, frames, steerings and etc. in trying to reach the commercially acceptable electric vehicle, with larger electric motors, controls and batteries, these would not hold up.

Previous attempts to convert U.S.-made automobiles and trucks to Electric Battery Power have been self defeating. Because of the initial weight of the frame, suspensions, steering, wheels, tires, body and etc.—large electric motors, controls and batteries have been needed to move the vehicles before you even put loads in them.

We still have molds for making fiber glass bodies of our previous small truck which we have converted to electric battery power. There are two reasons why we do not plan to use them (1) They are too heavy for our targets of weight. (2) Petro chemicals used in making fiber glass objects would further deplete available fossil fuel ingredients. In addition to our present planned production vehicle, we have designed a frame and body of aluminum for our four wheel steered vehicle, and are making a prototype of larger van with as much aluminum as is possible to use—in order to attain maximum performance.

Rather than go into the long period of organizing production of all the components needed for the entire vehicle, we decided to try to find a small vehicle in high production somewhere in the world. We first bought some light weight Japanese I/C automobiles (not sold in the United States) but on which there is a lot of experimentation in Japan. When we converted these to electric battery power, we were at first exhilarated because we were reaching our goals of performance. But alas, after considerable road testing they couldn't stand up to the extra weight of larger motors, controls and batteries.

We then had a small commercial van manufactured to our specifications. With some beefed up suspension we attained our goals in December 1973. Subsequently we had the stronger suspension and other amenities such as sliding doors included in a newer model, which was on display here. We have reached our goals of 45 mph and 100 miles per battery charge. This brings me to the main thrust of my message to you gentlemen.

To be realistic one must examine the history of small I/C vehicles after World War II. It wasn't until Volkswagens, Fiats, Renaults, Austins, and other foreign-made cars began to penetrate the U.S. market to a substantial figure that U.S. manufacturers started taking the small cars seriously. What did they do? Instead of producing small cars in the United States, they started bringing in cars made by their foreign subsidiaries, and are still doing it. In addition, a good number of U.S.-produced compact cars contain many components imported from the manufacturer's foreign subsidiary.

When Datsun and Toyota sales of pickups began to show a market for such vehicles, no U.S. manufacturer has started to make them (other than our aborted effort) and Ford imports the Courier Pickup and Chevrolet the LUV Pickup.

I am certain that the intent of the bill is to accelerate the manufacture and growth of electric vehicles as expeditiously as possible. To do this, would perhaps mean giving priority to vehicles designed to carry that average 350-lb. load which a Chrysler engineer said was the average for pickups in the United

States. Our vehicle has a 700-lb. pay load. U.S. automobile manufacturers will not go into production of a new model vehicle unless they see 40,000 units per year. Maybe 20,000 if it is a big-profit item.

In the first week of October this year, GM has displayed their new gas saving small car-made in their foreign subsidiary plants with the expectation of producing in the U.S. next year. Ford is coming out with a competitive model next year, probably made in their foreign plants. Both have a target of 40 MPG on highways. They are following in the footsteps of foreign competitors such as the VW Rabbit.

The conclusions for rapid Electric Vehicle growth are to be made from the development of economy cars in the United States as outlined heretofore. These are:

1. Light weight of the basic vehicle is the most important point in attaining maximum mileage for I/C engines. And this applies to the same with Electric Storage Battery power.

2. Foreign design and engineering of light weight vehicles and components must be utilized to a maximum until they become available in the United States.

3. U.S. manufacturers of such designs should be given priority encouragement by all departments of Federal, State and Municipal Levels.

For instance, besides the conversion of a Foreign small station wagon to Electric Battery Power, we have ready for production a similar sized vehicle of our design. We use an aluminum frame and body, foreign suspensions and steering, and U.S. Electric Components (as much as possible). We are also building a prototype of a larger version (twice the weight) with an Aluminum Frame & Body and U.S. Suspensions and steering. The production of our own requires lengthy plant facility, organization and personnel development. We intend to work on these as rapidly as possible after we start large production of the converted units.

4. To accelerate production of all three vehicles the following is required:

   a. As much latitude on government regulations as is reasonable, mainly that converted and production vehicles be required to conform only with Individual State licensing requirements prior to the 1966 NHTSA Safety Standards (See Separate memorandum).

   b. The importation of complete vehicles for conversion to Electric Battery power without NHTSA approval of customs clearance be allowed with the disposition of the I/C engines to be made only with EPA approval and under NHTSA regulations if proposed for use in any special vehicle. This would be in the event that the motors were not returned to country of origin.

5. The Administrator of the comprised Senate and House Bills may make direct loans to manufacturers of Electric and hybrid vehicles. To qualify for such loans, a manufacturer must have produced a prototype which can meet pre 1966 NHTSA Safety Standards prevailing in the State in which the manufacturer resides, in addition to meeting normal prudent loan requirements such as access to facilities, management and production abilities. Such loans could be handled by already existing SBA offices on such formulas as may be developed by the Administrator of the EV bill.

6. As an alternative to loans the Administrator be authorized to make progress payments to manufacturers of electric vehicles purchased by the U.S. Government up to 75% of the purchase price, and 10% more on delivery being allowed a 15% discount for having paid in full before delivery.

These last two are probably the most important provisions of an Electric Vehicle Bill. When we recommended loan guarantees for the House EV Bill, we had as an example a reasonably good assurance that the SBA would initially guarantee a working capital loan up to the maximum of $350,000. We had a commitment from a New York Bank to take part of the guaranteed loan if any of the bank in our manufacturing city of Seattle, Washington would handle the mechanics of the SBA loan and take at least a token part of it.

None of the major/local banks would touch it because we could not assure them of where the additional $1,000,000 would come from, we would need during the ensuing 12 month period, and probably $1,500,000 the following year if production and sales accelerated as we expected—without depending on U.S. Government buying. One bank's president (an old friend and neighbor of mine) said we should make a joint venture deal with a large company, immediately confirming the contention of the Business Week article's that because of the development capital shortage, only the large companies would be able to tap capital rces.

In N.Y. when asked about underwritings brokers respond—"Why should we get our customers into a new business in a new industry with a new product, with no earnings when we can put them in going businesses at a discount—such as companies listed on the New York and American Exchanges at one and two times earnings." That was earlier this year but there are still a lot of bargains on the two exchanges. This explains the point and is the major reason why the U.S. Government will have to be in the direct loan business on making advance payments.

Regarding relaxing the NHTSA safety standards as suggested in no. 4 of the foregoing, GM and Ford could have produced a 40 MPG Vehicle anytime during the last 50 years but they are doing it now for U.S. consumption. They and other large companies will not get involved in small economical electric vehicles until competition forces them to and that is from 5 to 10 years in the future. Therefore NHTSA regulations should be relaxed to enable new participants into the E/V field. I am thinking of Recreation Vehicle manufacturers around the country. They have the personnel, plants, management and experience in buying various vehicle components, making all or parts of the bodies. That puts them ahead of someone starting from scratch. All they have to do differently is to install the electric motors, controls and batteries instead of I/C motors, fuel tanks and accessories.

Additionally, manufacturers, experienced in small electric vehicles manufacturing, such as golf and industrial vehicles (including fork lifts) can be encouraged to go into commercially feasible E/V production. I think of the two, the latter should be given priority attention, because marrying the right electric components to vehicles are generally more successful when done by people with the E/V experience.

Some will come up with unprofitable products but good old American Competition will result in the best units surviving. In order to give all facets of the E/V production spectrum a chance to take off at the starting gate, manufacturers should be allowed to meet only State licensing requirements prior to the 1966 NHTSA Safety Standards.

In a desist order to Motorcycle Manufacturer Yamaha on its advertising, the Secretary of Transportation made the statement that any four wheel vehicle with sides was safer than a two wheel vehicle. Apparently, Yamaha had inferred their motorcycles were as safe as some automobiles.

Therefore, since cigarette packages are required to have the label:

"WARNING: The Surgeon General has determined that cigarette smoking is dangerous to your health."

"This vehicle does not meet the 1975 NHTSA Safety Standards but it can be licensed under pre-1969 (or 1966) requirements for licensing by individual States. It is considered to be more prone to occupant injury in the event of collision that vehicles meeting current NHTSA Standards."

The manufacturer could have a small label underneath which reads:

"The manufacturer of this vehicle considers it considerably less prone to occupant injury than motorcycles and even more so than bicycles."

SUMMARY

Recommendations to be considered—paragraphs of the foregoing:

4. (a) Electric Vehicles be required only to conform with Individual State licensing requirements prior to the 1966 NHTSA Safety Standards.

(b) Complete vehicles for conversion to Electric Battery power be allowed to be imported without NHTSA approval of customs clearance.

5. The administrator be allowed to make direct loans to manufacturers of Electric and Hybrid vehicles.

6. As an alternative to loans or guarantees, the Administrator be authorized to make progress payments to manufacturers of electric or hybrid vehicles purchased by the U.S. Government, up to 75% of the purchase price, and 10% more on delivery, being allowed a 15% discount for having paid in full before delivery.

[From the Seattle Times, Aug. 17, 1975]

YAMAHA AGREES TO ADJUST SAFETY CLAIMS

The Federal Trade Commission and the Yamaha International Corp. signed a consent order banning the motorcycle manufacturer from saying certain things about motorcycle safety.

In announcing the agreement, William C. Erxleben, F. T. C. regional director, said the company had been advertising that motorcycles, "with proper instruction, can be just as safe (as a car)."

Erxleben said "almost every statistic" proves otherwise and that the consumer agency felt the advertising was misleading.

The advertising, which ran in 1973, was part of a Yamaha "Learn To Ride" program.

Erxleben commended the concept of motorcycle-training seminars, but questioned the validity of the safety contention.

"No matter how thorough your training, in the event you become involved in an accident you will be less safe from injury while riding a two-wheel vehicle weighing several hundred pounds than when riding in an enclosed four-wheel vehicle of one to two tons," he said.

He said the agency and Yamaha recently conducted an independent survey of the program's 140,000 participants. The survey showed that a "considerable number" of those who attended the seminar felt a motorcycle was as safe as a car, he said.

To correct this impression, the F. T. C. has required Yamaha to send a letter to each of the participants clarifying contentions of motorcycle safety, Erxleben said.

Yamaha, one of the world's largest motorcycle builders, won't be required to run "corrective advertisements" for any misleading information disseminated.

The consent order, Erxleben stressed, is not an admission by the firm that any law has been violated, but carries the force of law with regard to future action.

Biographical Sketch of Jet Industries, Ltd.

Jet Industries, Ltd. is a Delaware corporation organized for the manufacture of electric battery powered and other vehicles. Its products consist of a small ELECTRAVAN with conventional steering and a similar sized MINITRUK with a four wheel steer for convenient parking. The latter vehicle also has a gasoline-powered version attaining 40 miles per gallon. In addition, they are developing a larger all aluminum electric van (except for running gear). Production facilities are in Texas and B. C., Canada.

The principals of the company are:

A. Forbes Crawford, President—who is also president of a Canadian company of the same name and Forbes International, Ltd. of Canada. Previously he was president of a truck manufacturing company and a tractor manufacturing company. In addition he has been associated with the investment and commercial banking business, as well as having interests in other manufacturing businesses.

W. L. Bales, Executive Vice President—is also president of Bales Engineering Co. of Texas, and a major shareholder in a number of private businesses. Previously, he has been the chief executive, founder, and a major shareholder in a truck manufacturing company, electric golf cart and industrial vehicle manufacturing company, and snowmobile manufacturing company.

Electric Vehicle "Breakthrough"

Jet Industries has engineered what it believes is a "Breakthrough" in Electric vehicle design with its current models of HIGH PERFORMANCE, LIGHT WEIGHT, RUGGED AND FLEET FOOTED PRODUCTS.

In predecessor companies the principals of Jet Industries had engineered and produced many thousands of three & four wheel electric industrial vehicles and golf carts. In addition, they had headed companies manufacturing tractors, snowmobile and gasoline powered trucks. For many years they had been experimenting with the conversion of the trucks to electric battery power with reasonably satisfactory results.

When the energy crisis of 1973 erupted, efforts were concentrated on up dating the engineering and design work on electric vehicles for better performance. It was concluded that the major problem of the electric vehicle industry was a matter of weight versus available energy. By endeavoring to convert existing production trucks to electric power, too much of the energy was expended moving the vehicle, the weight of which had pyramided because of the need for larger electric motors, controls and batteries. On the lower end of the spectrum, golf cart components—suspensions, steering, frames and etc. were not adequate for larger motors, controls and batteries to attain performance goals of loads, speed and distance per charge for satisfactory commercial use.

Jet Industries used Automotive and Aircraft techniques to develop new light commercial and passenger vehicles which in their opinion, have substantially attained the goals needed for a successful commercial application. The Company has developed two very utilitarian types in this field:

1. A station wagon-van with very finished body, interior and workmanship with conventional steering, multiple doors by driver's compartment, sides and rear, called ELECTRA-VAN.

2. A very Rugged strictly commercial type of Van with attractive appearance. It has four wheel steer (known as scissor-enabling it to park in congested parking space without having to back in), called MINITRUK.

JET'S VEHICLE STATISTICS

Miles Per Hour: 40–55; Miles per Battery Charge: 75–100. (Dependent on gearing required for level or hilly terrain.)

Retail Price: ELECTRA VAN $4,800*, MINITRUK on Request.

*Includes Southwind heater—not shown on demonstrator. Plus one twelve volt battery for auxiliaries.

Demonstrator will be in midtown ____________ for next week. Phone 212–689–9470 for appointment. Movie of four-wheel steer MINITRUK is also available.

JET INDUSTRIES, LTD.
PRODUCTS

SPECIFICATIONS

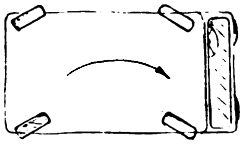
MINITRUK		ELECTRA-VAN
Electric or Gasoline Power Four Wheel Steer		Electric Power Only Conventional Steer
120"	Length	117.9"
56	Width	51
57	Height	63
72	Wheel Base	68.2
7	Road Clearance	7
70	Cargo Bed Length	71.8
52	" " Width	46.7
46	" " Inter. Height	49
1900 Lbs.	Curb Weight-Elec.	1934 Lbs.
1450 "	" " Gasoline	----
2600 "	Gross "	2600 "
2 Std.	Seat Capacity (Opt.)	2 Std.
84 Volt SCR	Electric System	84 Volt SCR
8 HP @ 3500	" Motor	8 HP @ 3500
25 HP	Intermittent	25 HP
110 or 220V 6-10 hr. rate	Charger	Same as MINITRUK
Ball & Joint	Steering	Rack & Pinion
4-Wheel Independent	Suspension	4-Wheel Independent
5.20 - 10 Tubeless	Wheels & Tires	5.00 - 10 Four Ply
Disc - All 4 wheels	Brakes	Drums all wheels
54 HP @ 4800 RPM	Gasoline Engine	-------
Automatic 3 Speed	Transmission Gasoline	-------
45 MPH	Speed Electric	45 MPH
100 Miles	Per Battery Charge	100 Miles
65 MPH	Gas. Engine Powered	-------
40 Miles Per Gal.	" " "	-------

BODY & FRAME

MINITRUK	ELECTRA-VAN
Aluminum - 2 Front & 1 Rear Door:- Standard (other opt.) MINITRUK has scissor steer for easy parking as standard equipt.	All Steel - 2 Front, 2 Sliding Side & 1 Rear Standard Conventional steering only.

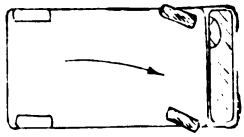
MINITRUK

Scissor Steer



ELECTRA-VAN

Convential Steer



LEFT:
Top - Both MINITRUK & ELECTRA-VAN are 3 ft. shorter than VW Beetle. But have same floor area as Datsun pickup.
Bottom- Chassis of gasoline powered MINITRUK - showing scissor steer.

RIGHT: (Elec. system same in both vans)
Top - Battery cover shown. Comes carpet covered in station wagon version.
Middle: - 12 Six Volt Batteries = 72 V.
Bottom: - Showing controls and motor.

ELECTRIC VEHICLE COUNCIL / 90 Park Avenue, New York, N.Y. 10016, Tel. 212.57

February 18, 1975

Mr. A. Forbes Crawford, President
Jet Industries, Ltd.
C303 - 230 Park Avenue
New York, New York 10017

Dear Mr. Crawford:

In response to your inquiry for counsel regarding your electric battery powered vehicles, it would appear to us that instead of trying to sell non-believers on the merits of your products, you should go through those institutions and government agencies which have expressed so much concern over the energy and anti-pollution problems. Through them, you may be led to contacts which might result in an accelerated interest in your efforts.

Maybe its exposure in Washington, D. C. could result in the executive and legislative branches of the government finding it an ideal second vehicle for use in the Capitol and suburbs, if nothing more than showing their constituents an example of one type of vehicle which could be used during the energy crisis and perhaps permanently, as part of the AMERICAN SCENE.

All of the discussions at the Electric Vehicle Showcase '75 held at Eisenhower Park, East Meadow, Long Island on February 6th, indicated a need for engineering light weight but strong vehicles in order to maximize the performance of electric vehicles and keep production costs in reasonable limits.

If you decide to go to Washington, do not hesitate to contact our office there (Mr. Glenn Lovin or Mr. William F. Boyle, Edison Electric Institute, 1015 18th Street, N.W., Washington, D.C. 20036; phone No. (202) 223-2720). Perhaps they can suggest some individuals to contact who may be interested in electric vehicles.

Please do not hesitate to call on us if you need someone to "Hold your Hand", as we are very confident of the future of electric vehicles.

Very truly yours,

E A Campbell

Edward A. Campbell
Executive Secretary

REYNOLDS ALUMINUM SALES COMPANY

February 10, 1075

Mr. A. Forbes Crawford
Jet Industries Ltd.
230 Park Ave. - Suite C-303
New York, N.Y. 10017

Dear Mr. Crawford:

I enjoyed attending the Electric Vehicle Showcase 75, which I found to be very interesting and informative. The Electravan vehicle which you displayed, seemed to attract a good share of attention from the various potential users who were present and I trust this is indicative of the success you may expect.

We at Reynolds certainly appreciate your efforts towards the development of a light weight electric vehicle and although we are unable to lend financial support to your venture due to the priority of other requirements within the corporation, we do feel strongly that the light weight feature is a most important component to its ultimate success.

Going into an extended period of fuel shortages and ecological considerations toward cleaner air, a vehicle of the type and design that you are promoting would certainly contribute to both of these causes. The attached brochure outlining our current TV program is evidence in part of the major commitment by the Reynolds Metals Company to the environmental considerations and energy conservation.

It was a pleasure to lunch with you and Don Crane and thank you for your interest in introducing me to a number of the other important people in the industry.

Sincerely,

E B Reynolds

E. B. Reynolds

STANDARD ELECTRIC COMPANY, Inc.

FACTORY AND OFFICES
3016 AUSTIN HIGHWAY • P. O. BOX 18127 • SAN ANTONIO, TEXAS 78218

March 17, 1975

To Whom It May Concern:

We have had the opportunity to drive, as well as ride in the "Electra Van" all electric 1/2 ton van demonstrator made by Bales Engineering Company.

It is a fine performing, easy to handle, well balanced delivery van. It has good acceleration and performs well.

It should be an answer for limited daily mileage and light delivery service.

Very truly yours,

STANDARD ELECTRIC COMPANY, INC.

Gerald Dubinski

Gerald Dubinski
President

KING INSURANCE AGENCY
General Insurance—Bonds—Real Estate Loans
1141 W. Sixth
Austin, TEXAS

Mr. William L. Bales
Jet Industries Ltd.
230 Park Ave. - Suite C-303
New York, New York 10017

Mar. 19, 1975

Dear Mr. Bales:

After having driven your Electro-Van vehicle, I am happy to say that it was a pleasure driving it in the hill country in and around Austin. I was surprised that the van would run 45 M.P.H. and that I drove it most of the day and it was not apparent that it had lost any of its power. That evening I just plugged it into a 110 watt curcuit in my carport and it was ready to go with the same power the next morning as it had been the day before.

There were a number of people that stopped me and wanted to look at the Electro-Van and inquired where they could buy one and how much it would cost. It looks like we are going into an extended period of fuel shortage and ecology toward cleaner air. An electric vehicle of this type would certainly contribute to easing both of these causes. It is my belief that there will be a great demand for this type of vehicle in the very near future.

Thanking you for letting me test drive the Electro-Van for two days.

Yours sincerely,

Dow King, Jr.

DK:em

T: File
Phone conversation

ULTIMATE ELECTRIC VEHICLE

Yesterday, George Hargreaves, Manager of the Public Service Department of the British Columbia Hydro Electric & Power Authority in Vancouver informed me that they had hired the Commerce Department of the University of B. C. to do a study for them. The staff first of all made an analysis of commercial vehicle use--that is daily mileage and so on--with large representative samples of commercial vehicle users in the greater Vancouver area. And the second thing they did was a fairly complex study of commercial purchaser preference and basically concluded that:

ELECTRIC VEHICLES THAT WERE AVAILABLE WERE LACKING IN TWO RESPECTS:

1. THE HIGH FIRST COST. 2. THE LIMITED RANGE

THEIR ANALYSIS SHOWED THAT IF EITHER ONE OF THESE FACTORS AND NOT NECESSARILY BOTH OF THEM, COULD BE SIGNIFICANTLY IMPROVED: -- THAT IS, IF THE PRICE COULD BE BROUGHT DOWN OR IF THE RANGE WAS INCREASED THERE WOULD BE A VERY SIGNIFICANT MARKET IMMEDIATELY.

When I quoted Mr. Hargreaves the figures of 45 MPH - 100 miles per battery charge and 7.2 lb. payload of our vehicle at a price of $ 4500-$4800, he "You have it made." Over a year ago he had been sent to Austin, Texas to test one our prototypes after he had finished with a symposium of electric vehicles in Washington, D. C.

As you can see from the figures below which were developed from published literature at the ELECTRIC VEHICLE SHOWCASE at the Salisbury Country Club last week, we have already attained the figures of performance and price suggested by the UBC study. As I mentioned on the telephone, I had lunch with Mr. Dnne Crane, Director, Office of Fleet Management, U. S. Postal System, Washington, D. C. and Mr. Edward Reynolds, [illegible] of Reynolds Aluminum Corp., and at that meeting both were very impressed with our performance figures and contention that the less energy required to move the basic vehicle, would result in better performance with a payload.

ELECTRIC VEHICLE STATISTICS

Manufacturer	Battronic	Otis	AMC*	JET
Miles per hour	30	45	33	45
Miles per battery charge	40	50	20	100
Volts	112	96	--	84
Weight lbs.	6,000	3,800	3,690	1,934
Payload	1,000	500	700	700
Wheelbase	94 1/2"	96"	81"	68.2"
Overall Length	145"	138"	136"	117"
Overall Width	78"	65"	70.62"	51"
Cargo Space	140 cu.ft.	70 cu. ft.	50 cu.ft.	90 cu. ft.
RETAIL PRICE	$16,330	$8,500	$5,598	$4,100-$4,800**

* American Motors Jeep **Lowest price is for MINITRUK---Highest for ELECTRA VAN

The EVI sold the Battronic to 50 Public Utility figures for testing.

Feb. 19, 1975

A. Forbes Crawford

western union Mailgram

[illegible]
[illegible] 05/14/75
[illegible]
[illegible] NEW YORK NY 05-14 [illegible] EST
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March 19, 1975

TEST REPORT
ELECTRA VAN WB 700

Beginning in January 1975 and through March 10, 1975, the following test was made by our firm vehicle. These made entirely in Texas, one being on miles along the Texas the designated of Fort Worth, Texas. This of streets which miles and covered regular city of blocks rail lines and sidings. Included five stop lights and speeds and on up to 40 m.p.h. This done for days with average 5n miles per day.

On the one hundred highway ransported Houston Texas and a straight miles hour o this was done at the upper range of the SCR controller and the unit was run until the batteries were completely "down". The unit had run over a flat course for 101.2 miles.

MPH	AMPS	Volts Average
0-5	0-20	11
6-18	22-40	29
19-30	41-75	58
31-40	76-207	81

During high torque periods, and this was usually as the unit accelerated "across the batteries", maximum of 207 amps was experienced but as the unit achieved speed, would top speed an pull about 88-91 amps. Tires standard 500-10 4 ply inflated 35 all The independent suspension is excellent and with driver and passenger, the [illegible] perfectly balanced. There is no noticeable "heavy" feel and the unit turns, corners and brakes much better than the writer believe. On the city driving test, the batteries were about 60% discharged at the end of the run, and full recharge was achieved in ten hours with the on board charger. The 12 volt battery which handles lights, horn, directional signals, etc. is charged with a separate charger on board that rec[illegible] current from the same source when the main charger is turned on. The gross vehicle weight in all tests 2,264 lbs. Acceleration test was made different days and 0-30 average was 12 seconds.

Controls this unit consisted of key ignition switch the unit "on", a forward, neutral, reverse, mounted in the center consol. Acceleration is with a standard foot accelerator, a standard hand parking brake is mounted in the center next to the FNR control. The battery manufacturer stated that the batteries should last from 700-1000 recharge cycles. The unit tested did not have a removable pack, but another vehicle not running was checked and one man could change the batteries in 5 minutes. Battery weight is 920 lbs. Vehicle weight is 1,074 lbs. making a total of 1,994.

Very truly yours,

Ernest Istook
Ernest Istook

This article is a good SUMMARY OF ELECTRIC VEHICLE DEVELOPMENT plagiarized by JET INDUSTRIES, LTD. from ROAD & TRACK for your convenience. The author was not acquainted with JET's products at time of article. Nor did JET's ELECTRAVAN & MINITRUK PICTURES (on page) appear in original article.

Alternatives to the Conventional Engine

ELECTRIC CARS—SET FOR ANOTHER COMEBACK?

BY DANIEL M. COSTIGAN

ONE OF THE more predictable side effects of the recent energy crunch has been the re-emergence of that perennial transportation standby, the electric automobile. Evidently, when it appeared to have been trounced into extinction by its more lively combustion-powered rival a half-century ago, the indestructible electric had merely gone into temporary exile. It has been returning sporadically ever since to haunt its detractors.

There were occasional rumblings of an electric-car revival during World War II when gasoline had become scarce, and again in the late 1950s when smog and noise had reached menacing proportions in several American cities. But the really big push was not to come until the great electric-car revival of the 1960s, with Ford and General Motors announcing dramatic breakthroughs in the development of modern electric passenger cars. That was late in 1966. By the spring of the following year all the big carmakers were busily developing electric cars, and a dozen or more prototypes had been built and demonstrated.

But after a couple of years of considerable fanfare, during which it looked for a while as if the end was near for the venerable internal-combustion engine, the climate suddenly changed and the electric car quietly retreated into its cocoon to await the next resurrecting crisis. As things turned out it hadn't long to wait. That crisis came with the Arab oil embargo late in 1973.

Two unfortunate things happen every time the electric car makes one of its periodic reappearances. First, people blithely forget that the electric is not the all-inclusive answer to fuel shortages and air pollution that it purports to be, and have to be repeatedly re-educated to the fact that you don't get something for nothing. Second, the concept of vehicles powered by electrical energy somehow invariably manages to pass itself off as something new and revolutionary.

On the first point there is, of course, something to be said for the centralization of energy conversion—for the positive effects it can have on conversion efficiency and the control of air pollution. To begin with, not all electricity is produced by the burning of fossil fuels. In the U.S. the figure is about 85 percent, part of the remaining 15 percent being produced by water power at dams. Of the 85 percent nearly half is produced by the burning of coal, which is still fairly plentiful. Moreover, despite opposition by ecologists the number of nuclear powerplants has continued to grow, their power-generating capacity having nearly doubled between the end of 1971 and the end of 1972 (from 8687 to about 16,000 megawatts).

As for conversion efficiency, Federal Power Commission statistics indicate that it takes roughly a pint of fuel to produce one kilowatt-hour of electricity at the source, and automotive engineers have determined that approximately a third of a kwh of energy would be required at the motor output of a practical electric passenger car for each mile traveled. (By "practical" I mean a car with a range of about 100 mi on a full charge and a speed capability of 50 to 60 mph.)

If at this point you are somewhat confused about the relationship of commercial power to battery power, just remember that in effect the electric car's battery is merely a device for temporarily storing power from an outside source. Where that source happens to be commercial power, and it normally is, the big loss in the process is in transmission of the power from the generator to the point of use. There is approximately a 50-percent cumulative transmission loss from power-station output to car-motor output within the charge-discharge cycle. But strictly from the standpoint of oil consumption this would be canceled by the fact that oil accounts for only about half the commercial electricity produced. Thus we have, in our electric, a vehicle that yields some 24 mi of travel per gallon of oil consumed, which isn't bad.

But then the availability of an electric with the capabilities described, and bearing a "reasonable" price tag, assumes some significant breakthroughs in the development of new, more efficient battery systems. Using existing technology such a car would have to be as heavy and expensive as a pair of standard limousines.

It bears mentioning, incidentally, that the 24-mpg estimate is if anything a conservative one that can be boosted according to whose statistics and philosophies you are willing to accept. Efficiency estimates will naturally vary; and it can be argued, for example, that the use of battery chargers overnight during normally idle hours will take up some of the slack in power-generating capacity, thereby making the whole electric utility operation more efficient.

But what of pollution? Doesn't one power-generating facility do as much polluting as a whole horde of combustion-powered vehicles? Obviously it does. In fact, GM engineers have determined that, in grams per mile of electric-car travel, pollutant emissions from powerplants burning fossil fuels would actually be greater than those produced by individual combustion-powered cars meeting 1975 emission control standards. In fairness, it must be said that the proponents of electric propulsion have been able to produce equally plausible findings to the contrary. Moreover, we must not overlook the fact that, being centralized, the pollution produced by powerplants should be somewhat easier to control.

As for the second point—the popular misconception of the electric vehicle as something relatively new and modern—one need only look in any reasonably comprehensive text on the history of the automobile to see how very old the concept is. Records show that an electrified carriage was built in Scotland as early as the late 1830s, and that even before the beginning of the present century battery-driven vehicles had set world speed records on at least two occasions.

Going a bit beyond the realm of the private car, the first electrically powered rail car was built and operated by a Vermont blacksmith as early as 1834 (it ran on batteries). And in 1886 two Englishmen, Campbell and Ash, built the first

TOP RIGHT

Jet Industries - ELECTRAVAN 45 MPH 100 Range Utility Commercial vehicle & stationwagon

BOTTOM RIGHT

Jet Industries - MINITRUCK - 4 wheel steer Elec. or Gasoline powered (40 M. per Gal.).

battery-powered submarine, which they named the Nautilus. Both inventions started trends, the culminations of which are still very much in evidence today.

By the end of the first decade of this century electric-powered land vehicles, both the rail and road variety, had become a common sight all over the civilized world. Both were somewhat restricted in their range of travel. The rail variety, which now ran on distributed power rather than batteries, was confined pretty much to intracity trolleys and short-haul interurban passenger runs, whereas the battery-operated road variety was strictly a town car.

The electric automobile of this period was all the vogue among the well-to-do, especially with ladies who wanted to do their own driving. It was quiet, clean, dependable, and simple and inexpensive to operate. Unfortunately its lacy virtues were no match for the sheer masculinity of its combustion-powered counterpart, in whose dust it eventually perished (temporarily, as it turned out).

The real reason for the eclipse was the comparative inefficiency of the electric car's motor. A fuel engine of comparable size and weight (including the fuel tank) not only had more power and a considerably greater range on a single fueling but could be refueled and on its way again in a matter of minutes. The electric began to flag after about 25 mi. and then had to sip fresh nourishment from a charger for hours on end. The demise was complete when the fledgling car-service industry had grown responsive to popular preference and geared itself exclusively to the combustion car.

ELECTRIC SYSTEM SAME ON BOTH VEHICLES.
Bateries (920 lbs.) 84 VOLTS on URBAN MODELS (total weight 1934 lbs.)
45 MPH - 100 Miles per CHARGE.
Batteries (540 lbs.) 54 VOLTS on IN-PLANT MODELS (total weight 1414 lbs.)
25 MPH - 65 Miles per CHARGE.

But even excluding the rail variety, electric vehicles in general have never really left us. In 1968 there were more than 40,000 in use on public roads throughout the world, most of them short-haul delivery vans and most of those in England. I recall that electric delivery trucks, most if not all of obviously early vintage, were still a fairly common sight on the streets of New York City as recently as the 1950s.

Then there are the on-premises industrial vehicles, such as forklift trucks, that have been in more or less general use in factories and warehouses since the early 1940s, and of which there are now at least 100,000 in daily operation in the U.S. alone. Offsetting the austere ruggedness of these chunky workhorses are a growing variety of sleek little electric personnel carriers, of which the golf cart is perhaps most familiar.

But despite its continued existence little was done to advance the technology of the electric car until the big pollution scare of the 1960s. The major automobile manufacturers took their cue from the statements of several influential public officials (including at least one high-ranking Cabinet officer) to the effect that the combustion-powered car was a menace to public health. With so much re-inventing of the wheel these days, the developments that came out of that brief but exceptionally productive episode are worth reviewing.

Ford's bid was a sodium-sulfur battery with 15 times the storage capacity of conventional lead-acid batteries. GM's was a dual offering: a newly developed battery with somewhat less storage capacity than Ford's and a fuel cell of the same basic type that had been used successfully as the electric power supply for the Gemini and Apollo spacecraft. GM immediately followed through with two prototype vehicles, each employing one of the two proposed power systems.

There were shortcomings, of course. The high storage capacity of Ford's prototype sodium-sulfur cell was obtainable only when→

the cell was heated to a temperature hot enough to broil steak (about 570° F). GM's silver-zinc battery was costly and short-lived, and its fuel cell was not only bulky and complex in its then-existing form but required three chemical reservoirs, two of which had to be replenished at 125-mi intervals. Other designs involved the use of precious (and therefore costly) metals and highly reactive (and therefore potentially hazardous) combinations of metals and gases.

Among the more promising new battery designs unveiled, from an initial cost standpoint, was the zinc-air, on which at least five big electrical manufacturers had already spent considerable development effort over a period of several years. It was built of inexpensive materials and was durable, but it offered a gain in capacity of only about seven times that of lead-acid batteries (as opposed to 100-times and greater gains cited for some of the more exotic batteries then under development). And like GM's fuel cell it required the pumping of a fluid electrolyte through its cells while in use.

As for the vehicles in this 1960s renaissance, probably the most imaginative was American Motors' Amitron, a sleek, teardrop-shape coupe whose 50-mph cruising speed and 150-mi (maximum) range put it well within the realm of practicality as a commuting car. Its comparatively lightweight (200 lb) battery supply consisted of a set of special lithium-nickel fluoride batteries for cruising and a separate set of nickel-cadmium batteries for acceleration. The car's range was stretched somewhat by a regenerative braking feature that converted the drive motor to a charging generator whenever brakes were applied.

But, as with all of the other moderately efficient electrics that had been developed so far, the attractiveness of the Amitron was dulled by the size of the price tag that would have had to be put on these cars were they to be made commercially available. The batteries alone, though less expensive than some of the other special propulsion batteries that had been developed recently, would still cost more than the price of a whole engine for a combustion-powered luxury car (the special batteries for GM's experimental Electrovair II cost $15,000 in 1967).

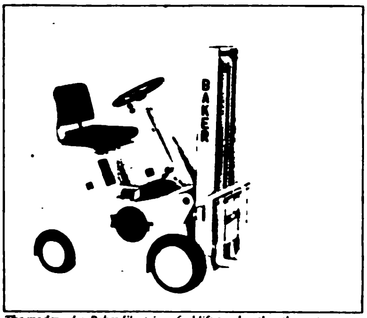
Despite all the obstacles, the people closest to the revival—automobile and battery-company executives and researchers—had remained optimistic about the electric car's posibilities. Dr Victor Wouk, who had directed the development of the batteries used in the American Motors prototypes, believed that we were now "closer than ever" to the time when electric vehicles could promise performance "as good as, if not better than, an ordinary gasoline car." And Leonard Crossland, British Ford's Assistant Managing Director, had noted that his company regarded its diminutive Comuta prototype as merely "a step in our program to develop a commercially practical electric car."

To the designer of electric passenger cars, weight and recharge time become critical considerations. The battery efficiency of passenger vehicles capable of cruising on open roads at reasonable speeds and for reasonable distances is measured in watt-hours per pound. About the highest rating to date of new-design batteries that have actually been road tested is 100, which gives the car a maximum range of about 150 mi before it has to take a three- to five-hour breather for recharging.

One way around these problems would be to provide electric cars for intracity use only, on a rental basis. There have been a number of formal proposals along these lines. Another way, not quite so easy to implement, would be to adopt a plan put forth by Cornell Aeronautical Laboratory in the 1960s (or a similar one advanced around the same time by Alden Self-Transit Systems of Westboro, Massachusetts), in which an electric car would run on batteries locally and on distributed power via an electrified guideway for long hauls. While operating in the guideway mode, the car's batteries would be recharged so that it would be ready for its next local trip on its own power. In 1967 the Cornell group foresaw their Urbmobile concept becoming a practical reality by the year 2000.

Still another way to circumvent some of the problems inherent in pure electric propulsion would be to effect a compromise in the form of a hybrid fuel-electric car that would be combustion-powered on the open road and battery-powered in the cities. During the late 1960s and early '70s GM, Ford and the U.S. Army investigated the practicality of just such a car. GM had in fact built and tested an imaginative prototype hybrid.

An early electric town car by Baker, circa 1910, was quiet and clean.



The modern-day Baker Electric a forklift truck rather than a town car.

The Elcar is currently available in two models: the 1000, with a top speed of 25 mph and a range of 35-50 miles; and the 2000, which will do 35 mph and travel 25-35 miles between its battery-recharge stops.

dual-powered by an AC electric motor and a low-emission Stirling external-combustion engine it co-developed with the Philips Company of Holland. If government intervention in the interest of public health should ever force industry's hand through a banning of combustion-powered cars from cities, the fuel-electric hybrid car is certainly as plausible a compromise as anyone could ask for.

Perhaps you are wondering what became of all these apparently earnest efforts to provide the public with a refreshing new breed of car. Unfortunately (or perhaps fortunately, depending on your point of view) by early 1969 a general change in the political and economic climate had acted to dilute whatever incentive there might have been to pursue a serious automotive revolution. When things recently began to look ripe for a new electric-car revival I queried some of those who had contributed to the advances made in the late 1960s.

GM responded with a terse statement to the effect that it is continuing to do research in the area, but that ". . . the problems—both technical and economical—are still quite formidable." Of the various technical reports they provided, the latest is dated January 1971. The subject is air pollution, but the report stresses the negative aspects of electric cars in general and concludes that it will be 20 years or more before they become a valid replacement for combustion-powered cars.

Most interesting of GM's more recent developments is the XLP experimental car, which operates from an improved lead-acid battery for acceleration and a zinc-air battery for cruising. It can do 60 mph and can go as far as 150 mi on a charge at half that speed. But it has one big drawback: recharging the zinc-air batteries requires replacement of not only the electrolyte (in six separate units) but also all 300 zinc plates.

Ford replied that it has continued its development of the sodium-sulfur battery, concentrating on fabrication of the solid ceramic electrolyte that is a key component of the system. A contract with the National Science Foundation has provided a welcome boost to this effort. But, though optimistic about the battery's potential, Dr. W. D. Compton of Ford's Research Center in Dearborn admitted in a recent talk that ". . . we have a long way to go to make this a commercial system."

Chrysler, who had operated at the fringes of the developmental thrust of the 1960s, failed to respond to a similar query for updated information.

American Motors reported that it has no current projects relating to electric cars. But, as it turns out, this is not entirely true. An AMC subsidiary, AM General Corporation (producer of the Jeep), was recently awarded a $2 million-dollar contract to produce battery-powered delivery vans for the U.S. Postal Service. This current activity, however, has no connection with the Amitron project of the 1960s, which according to the AMC spokesman was suspended when it was decided that the car had ". . . not come up to original expectations."

American Motor's sleek little Amitron electric could do 50 mph and go 150 miles on a single charge. It featured an electric braking system and had separate batteries for its cruising and acceleration power supplies.

Gulton Industries, who had developed the Amitron's batteries, notes that it had suspended its electric-vehicle research and development program in March of 1971, although it continues to provide special batteries and chargers to the transportation industry. In a recent interim report to stockholders it speaks of the energy crisis mainly in terms of the ill effects it could have on the company's operations.

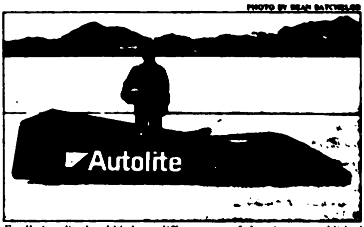
But as any perceptive observer will acknowledge, the conditions for a revival of interest in electric cars have never been better. And despite the apparent skepticism of the U.S. automobile industry the signs of an impending revival are everywhere.

The Japanese, for example, who recognize as well as anyone the dangers of building a civilization on a vital resource they don't possess, have a number of short-range electrics under development as evidenced at the 1973 Tokyo Automobile Show. The picture is much the same in Europe, where in Holland a computer-controlled intracity rent-a-car scheme has begun operation in Amsterdam, its fleet of midget electrics getting quick-charged from overhead feeders placed strategically around the city, and where at least three of Germany's automotive giants (Volkswagen, Daimler-Benz and Bosch) have become active in electric propulsion in varying degrees. In England, Enfield Automotive already has in production a two-passenger electric with a 50-mi range, and in Italy Zagato, the noted prototype builder, is currently mass-producing its popular Zele two-seater at the rate of 30 to 50 a day. The Zele will be marketed in the U.S. as the Elcar, a name that may ring a bell for some car buffs.

Here in the U.S., electric-car development has by no means ceased. The action has merely shifted (for the time being) from the big carmakers to a host of relatively obscure firms—notably Sebring-Vanguard, a Florida golf cart maker; Battronic Trucks, the electric-vehicle subsidiary of a big custom truck-body firm in Boyertown, Pennsylvania; Electromotion, of Bedford, Massachusetts; Die Mesh Corporation of Pelham, New York; and two Michigan firms: EVI, Incorporated of Sterling Heights (a maker of adult pedal cars) and Electric Fuel Propulsion of Ferndale. Some of these—Electric Fuel Propulsion, for example—lean toward the electrification of standard compact cars like AMC's Gremlin. Others design and build the electrics completely from scratch.

In addition, some larger firms outside the auto industry, notably Otis Elevator, have committed sizable funds to the development and/or production of electric vehicles. Otis alone is currently offering a variety of 14 different battery-powered vehicles include a 50-passenger bus. Going in a slightly different direction, Lockheed of San Francisco is among those developing vehicles in which an electric motor first revs up a flywheel of very special design and then becomes a flywheel-driven generator which powers the vehicle's drive motor. All told there are some 40 makers of on-the-road electric cars, trucks and buses throughout the world, some of them having been in the business for several years.

PHOTO BY DEAN BATCHELOR



Ford's Autolite Lead Wedge, a different sort of electric car, established a land speed record for battery-powered cars in 1968: 138.862 mph.

The present emphasis is on mini-electric passenger runabouts and short-haul utility and delivery vans. Here in the U.S. Sebring-Vanguard has already begun an anticipated production run of some 2500 Citicars, which have a top speed of about 30 mph, a range of about 50 mi on a charge and a suggested retail price of a little over $2000. As for the vans, there are strong indications that operators of large short-haul fleets like the Postal Service are looking at electric propulsion with more than passing interest. About 40 electric mail vans of various makes are currently in regular use in at least four American cities (Allentown, Pennsylvania; Cupertino, California; Lowell, Massachusetts, and Stockton, California), and the Postal Service has already placed an order for 350 additional units. According to reliable forecasts this number could easily bloom to several thousand by the end of 1975.

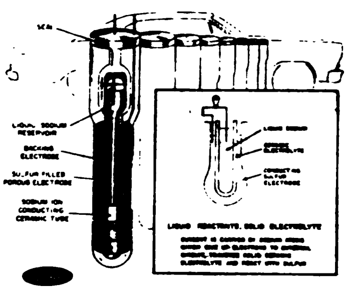
Although they may cost more than their combustion-engine equivalents (typically twice the price), there are definite long-term advantages in electric vehicles for government and commercial users. Most significant is the greater longevity and lower maintenance requirements. But not to be minimized is an advantage unique to the electrics: the fact that in stop-and-go city traffic they consume "fuel" only while in motion.

For these same reasons another class of electric vehicle, the battery-powered passenger bus, is receiving increasing attention these days, mostly from the transportation administrators of major cities. Similarly, electric utilities (hard-pressed though some of them are to meet present power demands) are evidently looking to the future by starting now to promote the use of battery-powered vehicles, at least within their own internal operations (by meter readers, for example).

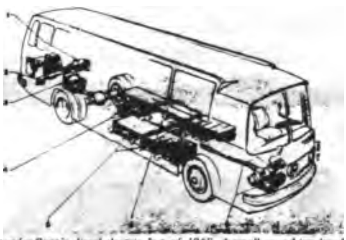
Technologically, the current crop of electrics has nothing resembling the sophisticated complexity of the prototypes developed by the auto industry in the late 1960s. The prevailing technology is typified in the vans and small buses produced by Battronic Trucks. All five basic vehicles in the company's product line, ranging from a truncated Minivan (500- to 1000-lb payload) to a sleek 25-passenger bus, use essentially the same basic electro-mechanical design: a GE 112-volt series-wound DC traction motor operated from two banks of more or less conventional lead-acid batteries. Though the batteries and motor are of the latest design within their class, the principal departure from traditional electric-vehicle technology is the use of new solid-state electronic control techniques.

The jerky starts and uneven speed transitions characteristic of early electric vehicles are eliminated in the modern version through use of an electronic "chopper" circuit consisting of transistors, capacitors and silicon-controlled rectifiers. The idea is to run the drive motor on pulsating rather than steady current so that its speed can be controlled by lengthening or shortening the pulses rather than by wasting some of the current in resistive ballast. The technique has been in use in forklifts and similar vehicles for several years.

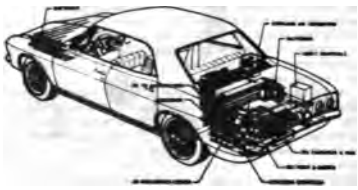
Does this return to a simpler technology mean that the highly sophisticated advances made by the U.S. auto industry in the 1960s are down the drain? Not at all. Obviously, the prototypes produced to date would be economically and technically impractical to put into production, and Detroit can't be expected to advance the technology much farther until there's been a showing by the motoring public that it genuinely wants and is willing to pay for such a radical new departure in automobiles.



Ford's sodium-sulfur battery was just one of many exotic new power sources developed during the electric-car revolution of the late 1960s.



Mercedes-Benz's diesel-electric bus of 1969. A small sound-insulated diesel engine (1) drives a generator, which charges five large lead-acid batteries (5). A single large electric traction motor (3) drives the rear wheels; blower (2) cools it. The batteries are cooled by another blower with its duct (7); (4) and (6) are parts of the vehicle's control system.



Despite its innovations, GM's Electrovair had a range of only 80 miles between recharges and required a set of extremely expensive batteries.

What is significant about the present reliance on the simpler, traditional approach is that it makes possible the production and marketing of electric vehicles at prices people can afford.

Logically, anyone who had to rise at 4 a.m. to take his place in a gas line two or three times a week last winter is a prospective customer for an electric car. If the same thing happens again (and there are many who predict it will) we can expect to start seeing electric vehicles in increasing numbers on highways and on the streets of our towns. At first they will be of the simple, low-speed, short-range variety. But as the market develops the big carmakers will be watching for their cue to put something more luxurious into production.

That something will most likely be some form of fuel-electric hybrid at first. But with the mounting pressures for exploration of new technological avenues, it is just possible that we may see some form of competitive all-electric passenger vehicle—one that can be used for reasonable distances at more or less normal speeds on the open road—go into volume production within the next three to four years. ■

ELECTRA VAN

84 **72 Volt *All Electric***

60 – 100 MILE RANGE – 40 MILE PER HOUR +/2 V=84

The Van that is Equipped with most Optionals Standard

ELECTRA VAN

the Light Commercial Van of Tomorrow

HERE TODAY!

Truly the very best in design for a true Electric Vehicle — Heavy Duty Brakes — Independent Suspension on *ALL* Four Wheels

Extra wide doors for easy access to *ALL* areas
SCR Controls —
Rear door — 42" wide, 36" high — stays open in any position

Batteries will change in 5 min. or leave in place and recharge in 6 hrs. — can be recharged on 110V or 220V

Sliding doors are standard — Front seat for two — standard optional rear seat — side doors 31" wide — 43" high

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ALL ELECTRIC ½ TON - 700 lbs.

CLEAN, SIMPLE, YET FULLY FUNCTIONAL FRONT SEAT — DRIVER ALWAYS EXITS CURB SIDE — CONTROLS INCLUDE ACCELERATOR, BRAKE, HAND BRAKE, SWITCH FOR ON — OFF AND A SINGLE CONTROL LEVER, FORWARD — NEUTRAL — REVERSE

NOT A UNIT DESIGNED FOR OTHER PURPOSES — A TRUE ELECTRIC VAN WITH AN ALL STEEL BODY — LONG SERVICE LIFE — MINIMUM MAINTENANCE — RUNS AT ½ COST OF GASOLINE MODELS — SHORT TURNING RADIUS — EXCELLENT HANDLING QUALITIES — LIGHT WEIGHT, ONLY 1934 POUNDS.

FEATURES: Off-street exit for driver — Large extra wide sliding cargo doors both sides — One piece rear door stays open in any position — Roomy, cabin — short turning radius — Long service life . . . very little maintenance — The light commercial van of tomorrow here today

SPECIFICATIONS:

Electra-Van

Length	117.9"	Batteries	14 220 AMP
Width	51"	Charger 110V or 220V	6-10 hr rate
Height	63"	Range approx. 75 miles (depending on terrain) 100	
Wheel base	68.2	Speed	45 MPH level ground
Road clearance	7.3	Steering rack & pinion	24-1 reduction
Cargo bed length	71.8"	Suspension (front & rear) independent, wheels 500-10 4 ply	
Cargo bed width	46.7"	Heavy Duty Brakes	
Cargo bed interior height, maximum	49"	Rear View Mirrors (3) STD.	
Curb weight	1934 lbs.	Cigarette Lighter	
Gross weight	2600 lbs.	Spare Tire	
Seating capacity (optional 4)	2 std.	Dual Jet Windshield Wipers	
Elec. system	84V SCR		
Electric motor	8 HP @ 3500 RPM		

The Van that is Equipped with most "Optionals" Standard

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Austin Texas 78703
512/263-2568 or 264-1814

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NY, NY 10017
212/689-9470

Mr. JAFFE. Mr. Cox, would you like to begin your testimony, please?

Mr. Cox. I would like to introduce John S. Gould who is the founding president of our company.

Mr. JAFFE. It's a pleasure to have you here today.

STATEMENT OF SPENCER R. J. COX, CHAIRMAN OF THE BOARD, UNIQUE MOBILITY, INC., ENGLEWOOD, COLO.; ACCOMPANIED BY JOHN S. GOULD, PRESIDENT

Mr. Cox. We will try to summarize our 10-minute testimony and will make the comment we have a 6-minute slide presentation that you may like to preview. In the course of the 8 years of our company we produced several hundred multipurpose vehicles but we have only produced one electric vehicle.

In the last 3½ years we have done considerable testing and refining on that vehicle. As a matter of fact, some of the performances that we have had to date are much higher than anything that has been spoken of in this room today. Our primary concept on all vehicles that we produce is to place them in our rental agencies that are similar to Avis and Hertz. We feel very strongly that the electric vehicle in its initial phases must be geographically controlled to insure proper maintenance to those vehicles.

We feel there couldn't be anything more detrimental to consumer acceptance than a man who owns an electric vehicle and can't get it repaired. When we move on and talk about other parts of the bill I think there is one part that we would like to emphasize. That comes under the safety and insurability. We wholeheartedly endorse the word safety but feel that there should be a very liberal approach to the safety standards initially set until this industry has an opportunity to evolve. Insurability—we have experienced the high cost of new products in the insurability area. We really feel there should be some considerable study and possibly allocations or incentives given in that area.

We are happy about the section on small business, because we are a small business. We also would like to recommend to the Senate committee that they incorporate the loan guarantee sections of H.R. 8800. Specifically, we would like to see the single borrower be able to borrow up to $15 million and we say that with one thought in mind. We have an attached article, appendix 2 to our testimony, that Chrysler will be introducing the Simca car, one model, one version of that car in 1976. They expect to spend $250 million on introducing that car when they already spent and build millions of these cars in Europe.

In the last section referring to technology, we would like to see that totally unrelated to a section on loan guarantees. Specifically, in General Motors' testimony, they referred to the House that they had spent $50 million, or anticipated spending $50 million for alternative power source research and engineering expenditures for 1975.

We would like to see that section increased to at least the $50 million level for the next 5 years. We feel that there is a lot of people involved in this, and in order to produce the successful electric vehicle industry, the criteria of dollars is most important.

Thank you.

r. JAFFE. I understand that you would like to make a slide presenon. Would you want to begin that now?

Mr. Cox. If you have the time we would like to take 6 minutes.

Mr. Crawford. As a matter of fact, if after he shows the slide, if some people would like to see about an 8-minute movie of a new vehicle which we have developed, I have a projector here. This is one of the reasons why we are anxious to have some latitude under the NHTSA Safety Act because ours is a 4-wheel vehicle.

For example, we have a deal with British Electric, and Portugal and other places to build a vehicle in Europe.

Mr. Jaffe. Why don't we begin with the slide presentation. Then afterward, if people would like to remain and see your film presentation as well, that will be fine.

One point, for all the witnesses, the committee will possibly be sending supplemental questions to follow up on some of the points raised in the hearing. A certain amount of time will be allotted about 2 weeks, in order for you to respond to those questions before the hearings are closed.

Thank you very much.

[The statement and attachment follows:]

Statement of Jim Cox, Chairman of the Board of Unique Mobility, Inc.

Senator Moss and members of this committee, I am Jim Cox, Chairman of the Board of Unique Mobility, Inc. With me today is the founder and President of our company, John Gould. We are honored to have been invited to appear before your committee and make comments on H.R. 8800 and S. 1632.

Unique Mobility is a small publicly held company headquartered in Englewood, Colorado, a suburb of Denver. December of this year will mark the eighth anniversary of Unique. During those years we have assembled several hundred multi-purpose vehicles and one electric car. To date, we have spent three and one-half (3½) years in assembly, testing and refining that one electric vehicle.

In recent years most of the vehicles we have produced have been shipped to Florida and Arizona and then rented to the consumer through rental agencies we have established, in a method similar to Hertz, Avis and others. This experience has taught us that geographically controlled fleets allow for proper maintenance. Through this method of fleet maintenance and geographical control we intend to introduce our Unique electric vehicles in order to prove their utility. We do not intend to sell our product to the individual consumer. We recognize that it will probably take resources far beyond ours to put the electric car into the family garage. Successful demonstration of electric vehicle fleets, we hope, would encourage our country's major automobile manufacturers to fill that gap. This new industry must evolve through the years, in much the same way as the television industry has in the last thirty years. In addition to this bill, the electric vehicle industry must solicit the voluntary support for current "off the shelf" component parts and services, new technology, finance, insurance and consumer acceptance from our major automobile manufacturers, battery manufacturers, utility companies, electronics industry, plastics industry, aerospace industry, banking and investment banking institutions, insurance industry and not to be overlooked, the news media.

We feel that companies like ours in this new industry can lay good foundations for its future growth with the help of H.R. 8800 and S. 1632.

Unique Mobility on behalf of our stockholders extend our warmest congratulations to the House of Representatives, the Senate, this Senate committee, all of those who have given and will give testimony and to the multitudes of believers who have contributed to the progress of electric vehicles.

The future of the electric vehicle and its contribution to our earth may possibly depend on the passage of this legislation and the successful implementation of its objectives. With this spirit for success we would like to contribute the following comments on H.R. 8800 and S. 1632:

Management

H.R. 8800 Sec. (5A), S. 1632 Sec. 5(A)

We would like to suggest that Mr. Robert Seamans, Jr., head of Energy Research and Development Administration, select a director of the "Electric Vehicle

Development and Demonstration Act of 1975." In our opinion this director needs to be a creative and innovative person. The act is very encompassing and the director could become very fragmented in carrying out the "policy's ends and goals" of the act.

Demonstration

H.R. 8800 SEC. 7(D)(1) LINE 9, S. 1632 SEC. 7(B) LINE 13

We strongly suggest the "development of initial performance standards and criteria" be treated on a very liberal basis throughout the course of this act, so as not to impair or discourage the evolutionary progress that will take place with time and experience.

Vehicle Safety and Insurability

H.R. 8800 SEC. 7(B)(1) LINE 20, S. 1682 SEC. 7(B) LINE 24

Safety—we wholeheartedly endorse the word but it may also imply massive amounts of money depending on the criteria set.

Insurability—this could be the demise of the total act. We have experienced the high premium of new product risk cost. Allocations or incentives should definitely be considered in this area.

Vehicle Introduction

H.R. 8800 SEC. 7(C)(2), S. 1632 SEC. 7(C)(2)

This entire section is an object of our concern. Maintenance facilities must be provided within a reasonable radius wherever electric vehicles are being used. The words "lottery will insure widespread use" are frightening when related to eventual consumer acceptance, if a person cannot get his electric vehicle repaired. We would also suggest restrictions to warm weather climates initially. We would suggest expert testimony from Don Crane, Director of Fleet Management for the U.S. Postal Service, on the subject of radius maintenance. Also of further assistance might be General Electric's Electric Vehicle Control Department in Salem, Virginia, and any of the battery companies regarding performance of lead-acid batteries in cold weather climates.

Encouragement and Protection of Small Business

H.R. 8800 SEC. 10, S. 1632

We are very encouraged by this section because we are a small business. At the risk of repeating ourselves, we feel we need the voluntary support of many big businesses, too.

Loan Guarantees

H.R. 8800 SEC. 11, S. 1632 NO PROVISION

We feel that Senate incorporation of loan guarantees is imperative to the success of this legislation.

We would like you to consider having this total section stand on its own merits and be unrelated to Section 13. We believe most companies planning production or in production will probably try to qualify under this section.

H.R. 8800 SEC. 11(D)(1) LINE 25

The word "by" is confusing to us. We would like to see the word "in" inserted in its place.

H.R. 8800 SEC. 11(E)

We solicit your consideration to increase the amount of guarantee of any loan for a single qualified borrower not to exceed $15,000,000 and the aggregate amount of guaranties outstanding under this section at any one time not to exceed $300,000,000.

The attached Appendix A, an article from the Minneapolis Tribune date Monday, June 30, 1975, reported by the New York Times Services, may be of interest to you. I would like to direct your attention to paragraphs 5 and 6:

"The reason that Chrysler executives decided on the Simca car, a source said, was that "we know what we have. All the bugs have been worked out. And we've a million front-wheel-drive cars in Europe."

Estimates within the company are that it will cost the company about $250 million to $300 million to build in this country. There will be some saving in the tooling costs, the source said, since existing tools in France can be copied.

Our major automotive manufacturers know what the price tag is to introduce a new model car to our society. Under this act we must be attempting to prove the concept of electric vehicles. Is it not reasonable to consider the approximate cost of introducing one new model with what is trying to be accomplished under this act.

APPROPRIATIONS AND APPROPRIATIONS ACTS H.R. 8800 SEC. 13(A) LINES 6–7 S. 1632 SEC. 12

We would solicit your consideration to exclude from H.R. 8800 the phrase "including the payment of loan guaranties and interest under Section 11."

With regards to the dollar allocations referred to in this section, from 1976 through 1980, we would like to refer you to the statement of General Motors Corporation given to the House Committee on Science and Technology on H.R. 5470 page 2 and quote, "Our total alternative power source research and engineering expenditures for 1975 are expected to be about 50 million dollars."

We suggest that you may consider it reasonable under this act to allocate 50 million dollars or more each year through 1980, without having Section 11 spill over into this section.

We would like to express our sincere thanks to the Committee for the invitation to appear here, to each of you for your time and, hopefully, for your consideration of our thoughts.

[From the Minneapolis Tribune, June 30, 1975]

CHRYSLER TO USE SIMCA AS MODEL FOR U.S. CAR

(New York Times Service)

DETROIT, MICH.—Chrysler Corp. has decided to use a Simca car that will be introduced in France this fall as the model for a compact it plans to build and sell in the United States. The earliest possible introduction date will be the 1976 model year, according to sources within the company.

The sources emphasized that the Chrysler version would have a body style designed here and many modifications to the drive train, such as a more powerful engine and an automatic transmission to suit the tastes of American consumers.

"We will build a whole new car," a company source said, "not just put a Chrysler shell on a Simca frame."

The Simca 1301 special has front-wheel drive, with an engine that is mounted sideways and a transmission that sits under the engine and uses the front axle as a drive shaft.

The reason that Chrysler executives decided on the Simca car, a source said, was that " we know what we have. All the bugs have been worked out. And we've built a million front-wheel-drive cars in Europe."

Estimates within the company are that it will cost the company about $250 million to $300 million to build in this country. There will be some saving in the tooling costs, the source said, since existing tools in France can be copied.

The new car will be only one of a series of subcompact cars that Chrysler plans to deliver. A source said that versions of Mitsubishi cars in Japan also are being planned.

The plans are part of a $1-billion program to redo most of the company's cars by 1980 with the over-all aim of making them smaller and more efficient.

The source said that it was primarily the pressure from the Ford administration and Congress for the automakers to make big improvements in fuel economy that led Chrysler to go ahead with its subcompact program, which has been on-again and off-again since 1969.

The Chrysler source pointed out that the market for domestic subcompacts has sagged considerably since the height of the energy crisis, when they were capturing about 14 percent of the total car market. Domestic subcompacts accounted for only 7 percent of the market in recent months.

[Whereupon the hearing was adjourned to reconvene on Friday, October 10, 1975.]

ELECTRIC VEHICLE RESEARCH, DEVELOPMENT, AND DEMONSTRATION ACT OF 1975

FRIDAY, OCTOBER 10, 1975

U.S. SENATE,
COMMITTEE ON COMMERCE, SPECIAL
SUBCOMMITTEE ON SCIENCE, TECHNOLOGY, AND COMMERCE,
Washington, D.C.

The subcommittee met at 10:15 a.m. in room 1318, Dirksen Senate Office Building, Hon. Frank E. Moss presiding.

OPENING STATEMENT BY SENATOR MOSS

Senator MOSS. The hearing will come to order. This morning the Special Subcommittee on Science, Technology and Commerce will conduct the second day of hearings on electric vehicle legislation. Two bills are before the subcommittee: S. 1632 and H.R. 8800, both entitled the "Electric Vehicle Research, Development, and Demonstration Act of 1975." I introduced S. 1632 on May 5, as a companion bill to H.R. 5470. The latter bill evolved into H.R. 8800, which was passed by the House on September 5 by a vote of 308 to 60.

During Tuesday's hearing we heard from Representative Mike McCormack of Washington State, who introduced H.R. 5470, as well as representatives of the electric vehicle industry. Today, we will hear from another strong supporter of H.R. 8800, Representative Richard Ottinger of New York, as well as two Government agencies concerned with new automotive developments: the Department of Transportation and the Energy Research and Development Administration.

We will also hear from representatives of a major industrial and a major academic laboratory, as well as an electric vehicle manufacturer. Hopefully, with the information developed earlier by the House, and the new information being developed by these hearings, the Senate Commerce Committee will have a firm basis for judging the merits of the proposed legislation.

Electric vehicles are hardly newcomers to the American scene. In fact, there were more than 100 U.S. manufacturers of such vehicles in the early part of this century. However, due to the availability of large quantities of inexpensive petroleum, the internal combustion engine gradually replaced the electric car, and few such cars were built after 1930.

Today, the conditions which led to the rapid proliferation of internal combustion engine vehicles no longer exist, at least in their original form. No longer is fuel so readily available, and it certainly is no longer cheap. Motor vehicles as a class have been identified as the

largest single contributor by weight to our national air pollution problem, and consume as much petroleum each day as we import from foreign countries. So, clearly, something has to change.

Two options come quickly to mind: Improve the fuel consumption, emissions, and other characteristics of traditional vehicles; and develop new types of vehicles which minimize these problems.

Electric vehicles fit into this latter category. They offer the promise of improved energy efficiency, as well as reduced emissions and noise. Most importantly, they provide a means by which to reduce motor vehicle demand on petroleum supplies. With electric cars, the required energy can come from a variety of sources: solar, geothermal, coal, nuclear, wind, and so forth.

It is for these reasons that the Congress is paying careful attention to the electric vehicle option. However, as we heard in the testimony on Tuesday, it is also recognized that electric vehicles have their problems. Since the early days of this century the fundamental problem has been the same: The energy that can be stored in a reasonable weight of batteries limits the vehicle's range and performance. Hopefully, some of our witnesses today will address the subject of advanced battery systems which show promise of overcoming these problems.

I will conclude these remarks by stating that I believe that electric vehicles will play an increasing role in our national life. It was the overwhelming opinion of the House of Representatives that the quickest way to define this role for the electric vehicle is by means of a demonstration program which will place present and future state-of-the-art electric vehicles out into every region of the country on a timely basis.

The House has clearly stated the opinion that the time for action is now, not 8, 10, or 20 years down the road. And I tend to agree. The country is facing many serious problems, and we can no longer delay in trying to solve them.

At this point, I would like to turn to our first witness, the Honorable Richard L. Ottinger of New York. Representative Ottinger has been a leader in this field, one of its most vigorous spokesmen, and we are very pleased to have you before the committee today. You may proceed, sir.

STATEMENT OF HON. RICHARD L. OTTINGER, U.S. REPRESENTATIVE FROM NEW YORK

Mr. OTTINGER. Nice to be with you, Senator Moss, as we share many mutual interests. You have been a pioneer in this field and I appreciate your taking the time and trouble to push this legislation along today.

I am glad to appear in support of the Electric Vehicle Research Development Act of 1975, H.R. 8800 and see it through. I have been interested in the development of electric vehicles for many years, introducing legislation in 1966 to start electric car research which was adopted as an amendment to the Air Pollution Control Act.

This year I introduced legislation, H.R. 7506, to promote research on electric and hybrid automobiles. During the past months, I have been actively involved as a member of the House Science and Tech-

nology Committee in the drafting of H.R. 8800, and I am proud of the bill that has evolved from the work of our committee and the committee staff.

I welcome this moment to share with you my thoughts on some of the specifics of this legislation, some of which are not covered in S. 1632.

First, I would like to reinforce the need for legislation such as that before you. A paper presented by Mr. P. A. Nelson of the Argonne National Laboratory at the Third International Electric Vehicle Symposium in Washington last February stated that: "the introduction of electric cars by about 1985 and a gradual build up to a total of 18 million cars on the road by the year 2000 would result in a cumulative savings of petroleum of 1.3 billion barrels of oil."

A study by the Center for Strategic and International Studies at Georgetown University titled "Understanding the National Dilemma" showed that in 1970 energy conversion losses from transportation are greater for transportation than for all the major energy-using sectors.

Not only would the use of electric vehicles save on the demand side of the energy coin, but it also would affect the efficiency of power source utilization since most electric generation would occur at off-peak hours, particularly at night. At the present time powerplants must be banked down at night because of the drop in demand.

The bill before you, H.R. 8800, is a very definite thrust to create a market and a development of vehicles for that market which hopefully will expand Mr. Nelson's projections.

I am not going to go into the sections of H.R. 8800 which deal with the scale and timing of the demonstration. The chairman of our committee, Congressman McCormack discussed the three-part development program. However, I would like to stress two important inclusions which are of particular interest to me: the inclusion of hybrid vehicles, and provisions to assure participation by small business.

In 1972, a market study commissioned by the Electric Vehicle Council showed that 42 percent of the people in this country would be interested in buying a short-range limited-speed electric car, and this is precisely the market that is envisioned by our legislation. Statistics from Battelle Memorial Institute presented last April at the Design Engineering Conference, indicate that a 20-mile travel range would suffice for 50 percent of the urban trips of all U.S. auto drivers, while a 40-mile range would cover 67 percent of such trips. I think from the testimony that we have heard that this is possible with current state of the art.

I'd like to say I demonstrated two different vehicles in my district and they all developed not only a tremendous outpouring of people curious in seeing the vehicle and trying it out, but a tremendous demand and letters that come to me asking where they can get one. I think there's no question of the demand for such vehicles as a limited-use, second car, and I'm sure you and I use a vehicle just to get from our homes to the Capitol every day.

It's completely feasible today and it ought to be pushed forward.

The future of electric vehicles is far greater than the current state of the art, for all electric vehicles. The potential exists for combining electric generation for urban driving with other systems more efficient for highway use on an all-purpose energy saving vehicle that

would also be virtually nonpolluting. It is therefore important to include concurrent research and development of those hybrid systems which may combine such technology as sterling engines, flywheels, or more efficient internal combustion engines with an electric propulsion system.

By combining different forms of energy there is the possibility of increasing the range of electric powered vehicles and still permitting significant energy savings and controlling of pollution. I note that S. 1632 does not include hybrids and would urge strongly that they be added.

Second, I wish to stress that a great deal of the research and development of electric and hybrid vehicles has been done by small companies. It is very difficult for these companies to get funds to promote promising technology. Inventors may lose all rights to their inventions if they are turned over to major companies and there is no real indication that major companies will push such developments.

Therefore, H.R. 8800, section 10, deals specifically with the encouragement and protection of small business by specifying that the Administrator of ERDA shall reserve a reasonable portion of the funds for contracts with small business, devise contract terms, conditions, and payment schedules to assist in small business, meeting the special needs of small business concerns, and make available planning grants for developing, submitting, and entering into such contracts. The loan guarantee provision in section 11 of H.R. 8800 with its limitation of $3 million to any one concern is particularly established to meet the requirements of small businesses.

Electric propulsion systems for cars have been underestimated and put down for too long, both in trade and popular publications. There has been a good deal of misinformation as well. Just recently Consumer Report issued a blast at safety problems with two cars which had nothing to do with their electric propulsion systems but rather with their body design. Unfortunately, this got headlined "Electric Cars Declared Unsafe."

The energy-saving and pollution-abating potential of electric cars hasn't been made clear nor their current feasibility. The legislation you are considering can do much to help achieve the great potential of these vehicles.

I certainly congratulate you on your effort to put this forward and I hope we can finally see a real push to the electric vehicle market achieved through legislation with both you and the House design.

Senator Moss. Thank you very much for your excellent testimony and for your leadership that extends back over a number of years in regard to the utilization of electric propulsion for vehicles.

You state that in your home district it's a curiosity to see an electric car, and people gather around because it is a curiosity. Is it your opinion that the widespread utilization of electric vehicles that the bills would require would change the electric vehicle from a curiosity to something that is more acceptable because the public knows more about it?

Mr. Ottinger. I think so, without question. When you tell them of my experience with the car which I demonstrated 3 years ago with the battery made by the company who then made the batteries for

our Moon missiles, it cost 50 cents to charge up your batteries. Those batteries go in the 200-mile range versus what it costs today to fill a tank of gasoline to go the same distance.

It becomes a very attractive opportunity for people. And they are anxious to know if they can get them. The situation is such that they are not really available in production quantities throughout the country. I hope we can promote that.

Senator Moss. The rise in petroleum costs have tilted the economics more toward the electric vehicle. Is that your point?

Mr. Ottinger. I think so. Of course, if we got into mass production, it would make a tremendous difference. In 1966, I tried to persuade the Post Office Department, Larry O'Brien was then the Postmaster General, to acquire electric vehicles for the Post Office fleet. Since the silver zinc battery was very expensive, I tried to persuade him to get the Treasury to rent out the silver, which it presently pays to store—instead of having to make those payments, to derive income from the renting out of the silver on the basis for electric cars.

And we came within a small fraction of persuading him to do it. I think this is an avenue we should pursue; and that is, having the Federal Government create a market for those vehicles substantial enough so that their mass production could bring the price down even lower.

Senator Moss. The Washington Post last September 17th published an editorial and entitled it "Federal Aid for Electric Cars," and expressed reservations about the passage of H.R. 8800, and I quote from that editorial:

> The direct intervention of the Federal Government on this scale into improving and merchandising an existing product is a dubious proposition. If, as one of the bills sponsored put it, industry is waiting for a market and the consumer is waiting for an industry, they'll find each other soon enough without the Government's help.

What is your response to that editorial?

Mr. Ottinger. Well, today we have an energy crisis of very serious proportions, as well as, too often forgotten, the pollution threat to our national health. The introduction of the electric vehicle would make a substantial difference since the internal combustion contributes to more than half of our pollution and uses about 25 percent of our fuel.

Whereas the market and the production may meet eventually on their own power, so to speak, in the course of time, I think that with guaranteed loans and with some accelerated Government research on batteries, we can hasten the day when this development takes place.

And I think that is worth doing because of the important national objectives that are involved.

Senator Moss. The President is suggesting $100 billion be devoted to research and development in order to find alternate sources of fuel because of the petroleum prices we are experiencing. What amount of money would be involved in funding H.R. 8800?

Mr. Ottinger. I don't remember off the top of my head what the figures were. But they certainly were modest compared to that $100 billion standard.

Senator Moss. I think it's around $160 million. And part of that is loan guarantees, so probably the Federal Government wouldn't have

to expend even that much. The point I am making is that these sums are minute, in light of the recent call by the administration for a crash program to develop new energy supplies.

Mr. OTTINGER. One of the things that really concerns me is that this country is a tremendous waster of energy. If we could reduce our wasteful consumption of energy by just the figure of 1 percent, we wouldn't have an oil crisis. We wouldn't have a gap at the present time. All the administration efforts are to increase the supply side of the equation, but with very expensive programs.

There are lots of difficulties with that. Whereas the ability to conserve energy, the electric car is one small element of that, it just is not being utilized. And I think our action should be far greater than that. You're going to hear from Mr. Heller and I'd like to impress that on him very strongly, that where lip service is given by the administration to conservation—the dollars and the effort and the personnel the agencies are putting behind that effort is infinitesimal.

I hope he will help us to change that focus, because each barrel of oil saved—virtually any of the things we have talked about in the conservation field is going to cost a fraction, compared to gasification of coal or through the other exotic new energy forms that we're talking about.

Senator MOSS. Thank you very much. I do appreciate your coming to testify before us this morning, Mr. Ottinger. And, again, let me commend you for the good work you're doing in this field. We hope that out of these hearings will come additional data so that we'll be able to act on this side and then perhaps in conference with the House, produce a really meaningful bill.

Mr. OTTINGER. Very good. I appreciate your efforts.

Senator MOSS. Thank you.

We will now ask Dr. Fred Holzer of Lawrence Livermore Laboratory and Mr. Ormsby, vice president and general manager, Research and Development Division, of the Lockheed Missiles and Space Co. to testify—I'm going to ask Mr. Ormsby to speak first and then introduce Dr. Holzer.

I must say we have an intriguing and complex subject to discuss; and we have very limited time. So, I'm going to ask all of the witnesses who appear this morning to attempt to condense and summarize as much as possible. We'll put the written statements in the record in full for use of the committee and the staff and study them carefully.

We'll ask you to go ahead, Mr. Ormsby.

STATEMENT OF ROBERT B. ORMSBY, VICE PRESIDENT AND GENERAL MANAGER, RESEARCH AND DEVELOPMENT DIVISION, LOCKHEED MISSILES AND SPACE CO., INC.

Mr. ORMSBY. By starting right at the nut of the problem, it's no secret that one of the current performance limitations on electric vehicle capabilities is the poor energy storage capability of that system. We need to improve greatly on the 14 watt hours per pound that is the current standard of lead batteries and achieve at least 100 to 150 watt hours per pound before the public can expect to have a car that will perform pretty much like his current liquid-fueled automobile.

A lot of work has been done to discover the optimum electrochemical cycle. And one of the things we want to talk about today is the subject of a joint proposal by Lockheed and the Livermore Laboratories to ERDA, based on the study made in our laboratories a few years ago.

I'm talking about the action of metallic lithium with oxygen; the source of that oxygen may be water or air. This particular electrochemical reaction contains 6000 watt hours of energy in the laboratory. We recognize laboratory figures are not representative of operational systems, but an operational system based on this laboratory performance should achieve about 200 to 300 watt hours per pound.

As a matter of fact, we have developed systems and have operated such systems which deliver this performance. These systems have been developed for military applications such as torpedo batteries. An automobile using this concept would require, say, 30 kilowatts of power; and it appears this could be put in a passenger automobile weighing about 2,000 pounds.

Again, in the interest of time Dr. Holzer will talk more about what that automobile would look like. Let me introduce a paper prepared by Lawrence Livermore Laboratories entitled "Lithium Air Battery" dated April 9, 1975.

Senator Moss. Thank you. We will read it with great care.

Mr. Ormsby. Let me not go into the details of how it works, but let's talk about how the operator would see it. Rather than recharge a battery which is the current method of using lead acid cells, a lithium-powered automobile would be taken to a "filling station" and there the lithium which had been consumed would be contained in a lithium carbonate solution. That solution would be taken out of the car and new plates would be put in the automobile and the car could then be driven off.

This filling station stop would take around 15 minutes, a significant advantage over secondary cells which have to be recharged over a considerable period like 5 to 8 hours. I don't want to leave the impression that all we need to do is to start out and put a little money in the program and drive out in such an automobile in a year or two.

There are a lot of problems to be solved and I want to emphasize that we have achieved this kind of performance with a working cell, but translation of that into an automobile and working out the economics takes some time and resources. One of the areas that must be examined is the economics of the use of lithium. There appears to be more than an adequate source of lithium, particularly when it is realized that the lithium is recycled, not consumed. It is reprocessed and stored in the solid state.

We think the known reserves, identified resources, are more than adequate for a substantial lithium automobile system. And I'm talking about a market here of around 20 million lithium cells.

Now, if these preliminary calculations are correct, it would appear that the lithium system would be competitive with a conventional automobile system if the cost of the fuel, lithium fuel, can be achieved at around 65 cents per pound of recycled lithium. Again, we think that could be done; but it needs further work to verify that.

Well, that is background; and we would like to comment on proposed legislation. The current proposal contemplates a careful 5-year

development for solving many of the problems inherent in introducing a new technology. We think that in parallel, Government laboratories such as Livermore, should conduct investigations of the technology because that is a very important aspect of the total economics.

We urge the Senate in its consideration of S. 1632 to consider extending the research and development effort to at least 5 years. With large scale demonstrations of lithium or other advanced chemical systems so the Nation could benefit from a full performance of the electrochemical automobile.

We urge that the funding level in H.R. 8800 be reapportioned to allow a total program of 7 years duration again with new technology demonstration vehicles procured in the 6th year of the program.

I mentioned several times our joint effort with Livermore Laboratories, let me introduce Dr. Holzer, deputy director of Livermore Laboratories to offer further commentary.

Senator Moss. Thank you. We look forward to hearing from you, Dr. Holzer, and then I may have questions for each of you.

[The statement follows:]

STATEMENT OF ROBERT B. ORMSBY, VICE PRESIDENT AND GENERAL MANAGER, RESEARCH AND DEVELOPMENT DIVISION, LOCKHEED MISSILES & SPACE CO., INC.

Mr. Chairman, Lockheed welcomes this opportunity to testify on the pending legislation concerning Electric Vehicle Research, Development, and Demonstration, together with our fellow researchers from the Lawrence Livermore Laboratories of ERDA. Lockheed especially wishes to note the timeliness of such legislation because, in our judgment. if a well-conceived effort to bring the electric vehicle into competitive use is launched this year, it will probably succeed in just about the time-space available prior to significant depletion of our domestic reserves of petroleum, about ten years. The technical logic of the bill is fundamentally quite sound, for there are few ways to operate an automobile in the forthcoming electric economy other than the electric storage/electric propulsion technique.

Since transportation is the largest single consumer of energy in the nation, it is eminently sensible to invest research efforts in pursuit of an acceptable electric vehicle. It is no secret that the limitation on electric vehicle performance today (and for the next few years) is the poor energy storage capability of present day batteries. We will need to improve greatly upon the 14 watt-hours per pound standard of lead batteries and achieve at least 100 to 150 watt-hours/pound of energy storage before the public can hope to have vehicles with performance that is useful enough to complete with liquid-fueled vehicles.

Fortunately, a variety of electrochemical storage couples have been devised in recent years which offer the promise of meeting these goals. The proposed legislation is most timely in that ERDA has the strong possibility of developing a full-performance battery over the next five years. One of these candidates is the subject of a joint proposal by Lockheed and the Livermore Laboratories to ERDA, and is based upon a fundamental discovery made in our Palo Alto Research Laboratories a few years ago, the electrochemical reaction of metallic lithium with water and oxygen (or air).

The lithium-air couple will liberate just over 6,000 watt-hours of energy in the laboratory. Fundamentally, this couple is the most energetic electrochemical reaction known and offers, for the first time, a whole new technology which is competitive with the gasoline-air couple, and superior in many ways.

I hasten to add that a complete system will include a considerable amount of ancillary equipment and will not realize the high theoretical energy density value of the basic couple, but a practical system should achieve 200 to 300 watt-hours/pound of system weight, well beyond the threshold of useful storage. In point of fact, military systems developed by Lockheed have already achieved energy densities comparable to those for such applications as torpedo batteries and sonobuoys. The automobile system of say, 30 kilowatts of power, when in-

stalled in a passenger car of 2,000 pounds curb weight will provide it with a useful range between refueling of 200 miles. Its acceleration from 0 to 40 miles per hour will be 10 seconds, and it will be able to attain a maximum cruising speed of 60 miles per hour.

I wish to introduce at this point a report prepared by the Lawrence Livermore Laboratories, entitled: "The Lithium-Water-Air Battery: A New Concept for Automotive Propulsion," dated April 9, 1975, which contains a detailed examination of this technology and its clear implications to national energy needs.

I do not wish to dwell at length today upon the workings of the lithium cell, except for its implications to the pending legislation. The lithium cell technology allows the motorist to change over to electric vehicles with a minimum of dislocation. Not only is the performance of his vehicle similar to the gasoline automobile in speed, range, acceleration, and load capacity as earlier exemplified, but refueling would be accomplished simply by exchanging lithium byproducts (lithium carbonate) for new lithium anodes at a fuel station. Rather than recharge a battery for five to eight hours, we propose to operate in the manner of a fuel cell, wherein fuel (lithium) and oxidizer (air) are continuously converted to electric power and byproducts. The byproduct, lithium carbonate, is recycled back to lithium for reuse. Thus, the operator of the vehicle requires about 15 minutes to "recharge" or refuel his vehicle.

I do not want to leave the impression, Mr. Chairman, that this technology has been sufficiently developed to allow its exploitation and installation in electric automobiles without an extensive program of research, development, prototype building, and evaluation. Not only are there many problems yet to be solved in the engineering realization of this battery to a car application, but the economics of producing lithium and recycling its waste product lithium carbonate will have to be examined in detail.

For instance, the domestic production of lithium was 5,000 tons in 1974, and the known reserves are 500,000 tons. This is considered to be sufficiently adequate for the introduction of lithium batteries on a reasonably large scale if production rates are increased above today's level. Expansion of the domestic supply will have to occur if very large scale demands of lithium batteries, say 20 millions, were to be realized. Identified resources, at present not exploited, in the Imperial Valley of California and the Great Salt Lake of Utah, account for almost 1,700,000 additional tons. Lithium recycling from its carbonate, on the other hand, at present is done on a laboratory scale. It will have to be scaled up to highly efficient industrial plant size to insure that the price of the reprocessed lithium is sufficiently low to allow competitive automobile operating costs. Along these lines, calculations by Lockheed and Livermore indicate that a cost of about $.65/pound of recycled lithium is required and probably achievable. I'd like to stress, Mr. Chairman, that the recycling scheme recovers about 90% of the lithium carried in the automobile, there by ensuring a small useage of the domestic resources of this metal.

In view of the newness of this technology Lockheed's proposal to ERDA contemplates a careful, five-year development schedule for solving the many engineering problems inherent to introducing a new technology. In parallel, Livermore will conduct basic investigations of the technology and research of the technique or recycling of the byproduct, lithium carbonate. Both organizations will investigate the many implications to society of large-scale introduction of the technology in automobiles.

Lockheed urges the Senate in its considerations of S. 1632 to consider extending the research and development effort to at least five years, with some large-scale demonstrations of lithium or other advanced electrochemical systems to follow that time in order that the nation may benefit from this full performance electrochemical automobile.

We urge also that the funding level described in H.R. 8800 be reapportioned to allow a total program of seven years duration, with "new technology" demonstration vehicles procured and deployed in the fifth and sixth years of the program.

I have referred to our proposed joint effort with Lawrence Livermore Laboratories several times today because I am convinced that a closely knit government-industrial team will be needed right from the outset of the program. I wish now to introduce Dr. Alfred Holzer, Deputy Director of Lawrence Laboratories, to offer commentary.

STATEMENT OF DR. FRED HOLZER, DEPUTY DIRECTOR, LAWRENCE LIVERMORE LABORATORIES

Dr. HOLZER. Thank you, Mr. Ormsby.

Mr. Chairman, I appreciate the opportunity to appear before this committee today on behalf of the Lawrence Livermore Laboratory. We at Livermore have for a long time been concerned about the total dependence of the transportation sector, and in particular the private automobile, on petroleum. The energy to generate electricity, to power industry, and to heat homes, can all be obtained from a variety of fuels; present cars and trucks depend entirely on oil. We believe that the development of a practical electric vehicle offers one opportunity to decrease this dependence and introduce other fuels into the transportation sector.

The heart of such an electric vehicle must be its energy source. The absence of a battery able to propel a practical automobile has up to now prevented such a vehicle's successful development. I would like to convey to you some of the reasons why we at Livermore believe the Lockheed invention represents a breakthrough capable of fulfilling this role; why we regard this class of batteries as unique; and why we are so enthusiastic about the prospect of joining Lockheed in this project.

I also want to modify this optimism with a word of caution: The research has not yet been done, and our joint proposal is still being evaluated and considered by the ERDA. The document which Mr. Ormsby submitted to you, and some of our more recent work, represents a preliminary examination only. Nevertheless, this examination has suggested the potential which might be realized by research on advanced concepts.

I would like to show you the first table in my testimony; it lists some of the specifications we believe could be achieved in a full-performance electric vehicle powered by a lithium primary battery. I will explain and elaborate on these numbers later in my testimony.

[Table I follows:]

TABLE I

Vehicle performance and specification goals

Range	miles	[1] 200
Cruise speed	miles per hour	60
Acceleration 0–60 miles per hour	seconds	25
Vehicle curb weight	pounds	2,000
Weight of batteries	do	500

[1] Can be readily extended.

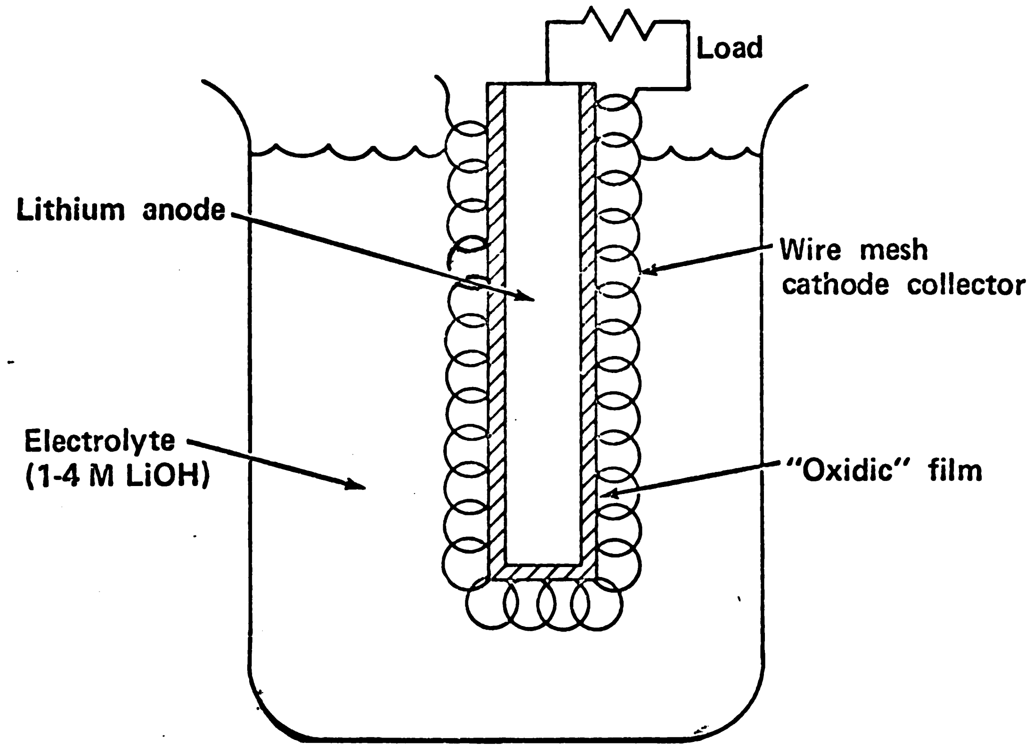
Dr. HOLZER. As you can see, we believe that a range of a minimum of 200 miles, which can be readily extended, can be achieved with a speed of 60 miles per hour, and an acceleration of 25 seconds to 60 miles an hour; this is comparable to many of our existing smaller automobiles today.

The total vehicle weight would be about 2,000 pounds, about one-quarter of which, or 500 pounds, would consist of the battery.

Figure I shows a very schematic view of one cell of the lithium water battery.

[Figure I follows:]

THE LITHIUM-WATER BATTERY PRODUCES POWER... AND LITHIUM HYDROXIDE



It is really quite a different battery than the one we are used to. A lithium plate forming the negative electrode and an iron screen—the positive electrode—are pressed together with a force of up to 30 pounds per square inch. When a load is connected to the terminal, and an electrolyte is introduced, the cell can be discharged with very high power and energy. Rather than shorting out internally, as one might expect, a thin, strong film forms on the lithium surface, separating it from the screen. Separators or spacers are therefore unnecessary and high performance is obtained. In the lithium-water-air battery, the positive electrode is a specially treated graphite plate.

As current is drawn from the battery, more and more of the lithium dissolves into the battery electrolyte. For proper operation the concentration must be controlled; we believe this can be done by precipitating the lithium in solution with carbon dioxide, CO_2, forming lithium carbonate. By now, I think that some of the special characteristics of this battery are becoming clear to you; like other primary batteries, it cannot be electrically recharged but can be mechanically recharged or refueled by a new supply of lithium plates. Sixteen pounds of lithium would propel this vehicle about 200 miles; an 80-pound charge would extend this range to 1,000 miles. The lithium consumed is not destroyed but would be recovered from the lithium carbonate and reprocessed into new electrodes. This requires electricity; in that sense the battery is "recharged."

An artist's concept of the service required by a vehicle operating on the lithium battery is shown in figure II. Carbon dioxide would be replenished and lithium carbonate removed every 200 miles, and new electrodes installed every 1,000 miles.

[Figure II follows:]


THE LITHIUM-WATER-AIR BATTERY
CONCEPT FOR ELECTRIC VEHICLES
1000 MILE SERVICING
•REPLACE LITHIUM ANODES
•ADD CARBON DIOXIDE
•REMOVE LITHIUM CARBONATE
200 MILE REFUELING
•ADD CARBON DIOXIDE
•REMOVE LITHIUM CARBONATE

Dr. HOLZER. Another design concept for this battery is to combine it with an advanced secondary battery—an all-electric hybrid. The secondary battery with a 50-mile range could power the car for all the short trips (perhaps 75 percent of the mileage) and could be recharged in the normal sense. The lithium battery would be reserved for those occasions which require higher speed and range. Under those conditions CO_2 would only be needed on the average every 800 miles, and lithium replacement every 4,000 miles. We believe operating costs for this dual-battery hybrid would then be competitive with gasoline-powered cars and provide comparable performance.

Another important point to make with respect to this figure is the following: A great deal of work is needed before one might hope to see the first such "service station." Much research, development, and demonstration is needed on the basic battery. Much is to be learned about the processes underlying the operation of this battery; lithium reprocessing techniques must be analyzed and improved; and optimum vehicle design must be determined; and the area of economic, environmental, and social implications must be thoroughly examined and evaluated.

We believe an orderly program to carry out this needed research may require about 5 years. This should be followed by a prototype testing and evaluation program which might take an additional 3 to 5 years to complete. It is our belief that the potential of such a full-performance electric vehicle warrants starting the initial research.

Thank you very much, Mr. Chairman.

Senator MOSS. Thank you, Dr. Holzer. That is a very intriguing exposition of the kind of research you are doing now and the possibilities of developing a fuel cell or a battery, whichever you are going to call it, with the use of metallic lithium. And this does have great promise.

Does this lithium battery provide electric current that is comparable to the lead-acid battery? I am thinking in terms of your hybrid. Do you just go over from one to the other utilizing the same amount of voltage and all the rest?

Mr. ORMSBY. Yes. The vehicle we are talking about is a vehicle which has a lithium cell, as well as a secondary type battery, and the lithium cell could be used to charge the battery at traffic lights and so forth.

So, yes; the kind of electricity is the same kind.

Senator MOSS. Would the hybrid increase the weight of the vehicle?

Mr. ORMSBY. A little bit; yes. But we are not trying to get the big range out of the rechargeable system. And therefore the weight is not as it would be if you are trying to get 200 or 300 miles out of the secondary cell.

Senator MOSS. In other words, you are saying you would have a normal-size lead-acid battery take over in certain situations?

Mr. ORMSBY. It would be bigger than the lead acid you see in your current automobile, but not as much as a vehicle solely powered by a secondary cell.

Dr. HOLZER. Mr. Chairman, we see that if one could develop a hybrid vehicle embodying two advanced batteries, one a secondary one and one a primary one, one could perhaps realize the advantages in-

herent in both of these systems, that is, the speed and the range inherent in the lithium battery, together with some of the improved economics and normal recharging procedures inherent in the secondary battery.

Senator Moss. In the recommendations that you both make for a longer period of time to be mandated in the legislation due to the need for further research and development, wouldn't it be possible to go ahead on lead acid batteries right now, and this research continue concurrently?

Mr. Ormsby. It could. I guess our position is that we don't think that should proceed at the expense of the more sophisticated system. That is really the point we are trying to make.

Senator Moss. When Congressman Mike McCormack was before us, he said that batteries are a primary area in which the experts agree that major progress can be made in a short period of time.

Dr. Edward David of Gould, Inc., testified before Representative McCormack's subcommittee, that a new lighter weight nickel-zinc battery could be developed at competitive prices within 2 years, if a vigorous development program were initiated today.

Do you agree with that statement?

Mr. Ormsby. We have a slide here; and I would like Mr. Galbraith to comment on it.

Mr. Galbraith. Mr. Chairman, if I may extend Mr. Ormsby's remarks a little. There is no question that a nickel-zinc battery can be developed. It, however, would fall short of the objective of developing an electric car which had utility comparable to a gasoline engine car. It would be superior in energy density to the lead-acid car. You can get a lot of this into prospective by an examination of this tabulation. What we are showing here is the theoretical and practical potential of almost all of the couples that are known electrochemically.

We have modestly put lithium-water-air at the very top of the list. It is, however, probably the most energetic couple we know of, and its total energy density is essentially comparable to that of gasoline cars.

Nickel-zinc, as you can see, does represent an improvement over a lead battery, potentially.

I don't want to take a thing away from it, but it does have its own peculiar difficulties, and I think Dr. David's testimony is probably accurate. It can be made into a useful device in a reasonable time, but does not offer the potential of an ultimate solution to the problem.

Senator Moss. You are saying it is a step up from lead acid?

Mr. Galbraith. It doesn't offer the possibility of a full-performance car that could compete with a gasoline engine car. But it is better than a lead-acid battery car, I would think.

Thank you, Mr. Chairman.

Senator Moss. Would you consider it economically feasible to press the development of intermediate batteries, while we are waiting for the lithium cell to be developed?

Mr. Ormsby. I would recommend that—you see there are a lot of options there. I wouldn't think we would recommend spreading our resources across the range of possibilities. We agree with the development of the current technology. But we feel strongly that we should be concentrating at the upper end of that scale where we see the possibility of competing with the current gasoline automobile.

Senator Moss. What are the safety implications of lithium-water batteries? Do they pose any special problems in the event of vehicle collision?

Mr. ORMSBY. Yes. Any time you have a high-energy source stored in a compact space, you have a hazard. So any system which packs a lot of watt hours into a given pound or volume such as gasoline, must be considered from a safety standpoint. It is one of the things that would be looked into with the development program we are talking about.

Senator Moss. Would a reasonable proposal be to develop some type of fracture-proof container, would that answer the problem?

Mr. ORMSBY. That is a possibility; yes.

Senator Moss. As you know, these bills that we are currenty considering have a demonstration program. This provision you have suggested might have its time schedule extended. But do you see any advantage in going ahead with demonstration now, rather than postponing it awhile?

Mr. ORMSBY. The program as proposed in the two bills?

Senator Moss. Yes.

Mr. ORMSBY. I think there is an advantage to it. Our concern is that the primary thrust of the bills be devoted solely to that. The objectives of the bill, as you commented earlier today, such as increasing public awareness, and so on, would be important byproducts. Our concern is that the effort be limited to that. I think there is a hazard that the public would get a restricted view of what an electric automobile could be and can do if the bill in its current form is enacted and implemented.

And I think that is a disadvantage of concentrating the effort on the current technology.

Senator Moss. So, although you think a demonstration program would be worthwhile, you believe we must continue to place significant emphasis on research and development to develop the fuel cell that you have been discussing?

Mr. ORMSBY. Yes. I think ultimately the American public can expect and should have a vehicle that performs as near as possible to what we have become accustomed to in terms of comfort, economy, and so on.

The only way we see to do that is to go into the development of the more sophisticated system in conjunction with the shorter term solution.

Senator Moss. You indicate that your program contemplates a recycling of the metal lithium. How common is lithium as a metal? Is it highly expensive or is it rather common?

Dr. HOLZER. Perhaps I can answer that question, Senator Moss. Our present lithium production in the country is not very large. It's something like 5,000 tons per year. It's primarily limited because its use is quite restricted at this time. Our resources, however, are much larger than that.

The total reserves, meaning recoverable at present prices, are something like 400,000 to 500,000 tons. The resource in other presently uneconomic deposits is about 2 million tons. So we have quite a bit domestically. In fact, your state of Utah has about half of the resources.

Senator MOSS. I was going to get in a plug about all the mineral resources we have in Great Salt Lake.

Dr. HOLZER. In that case, let me get a plug in for California which has almost all of the other half.

The electrochemistry of lithium, is much like that of sodium. And sodium these days is produced at a price which is roughly comparable to the one that Mr. Ormsby mentioned, about 70 cents per pound lithium equivalent. So I believe we're quite well off with respect to future lithium supply.

Senator DOMENICI. What does the 2 million tons equate to in cars?

Dr. HOLZER. I think I can answer that. We believe 25 million electric vehicles might require something like 400,000 tons of lithium. Now, that is actually twice the loading in the vehicle itself.

Let me make that a bit clearer; 25 million vehicles would actually carry something like 200,000 tons of lithium around with them and another 200,000 tons may be assumed to be going through the recycling process at the time.

Senator MOSS. In the reclamation of metallic lithium, electric power is required. How does that figure into the equation of the expense of using this type of battery as against, say, a lead-acid battery?

Dr. HOLZER. This expense, of course, is reflected in the price of the recycling of the lithium, Mr. Chairman, and again present prices and present costs have to be taken with some cautions because the quantities recycled and used are so small. At present they're higher than what I've mentioned and can be quite misleading. In our conversations with representatives of the Foote Chemical Co., the largest producer of lithium in our country, we understand that costs could be substantially reduced as soon as one talks about sizable quantities.

Mr. ORMSBY. Currently, it's being done on a laboratory scale only.

Senator MOSS. Well, I find this very intriguing and certainly it indicates the possibility of getting a fuel source that is almost comparable to gasoline utilized in an internal combustion engine with respect to the rate of acceleration, speed of travel and all the other factors we expect of passenger automobiles.

If we could have the charts, any that have not yet been submitted, placed in the record, it may be that after we have studied them, we may want to write and ask you additional questions because this is really opening a new field of inquiry. And it's very important to us.

I'd like to have my colleague from New Mexico ask any questions he may have. He seems to be as interested as I am.

Senator DOMENICI. Let me ask you this: I'm not on the Commerce Committee but I'm on Public Works and have developed a genuine interest in where we're going in R. & D. efforts in terms of alternate energizers for individual mobility.

Now you say that you're working with ERDA now. Is that correct?

Dr. HOLZER. I think Mr. Ormsby might answer that. I represent the Livermore Laboratories which is operated for ERDA.

Senator DOMENICI. But this project is negotiating with ERDA.

Dr. HOLZER. That's correct.

Senator DOMENICI. How does this mesh with existing law?

Dr. HOLZER. Well, perhaps I can just spend a minute telling you how this came about. As I indicated, we at Livermore have been quite

concerned with the energy problems that we have in general and focusing on transportation, which is a very large energy user, in particular. We realized, as the committee has, that electric vehicles offer one possibility or opportunity to diversify the use of energy in transportation.

In so doing, we came rather quickly to the realization that present battery systems do have severe limitations; and after all, the battery is the heart of the electric vehicle. In seeing where the forefront of research and development was being done in the battery field, we became aware of the work at Lockheed. We talked extensively with their people and as part of that interaction, became aware of many of the things that we at Livermore could perhaps contribute by joining with Lockheed in broadening, accelerating, and supplementing Lockheed's capabilities and directions that Lockheed was taking.

This is essentially how these joint proposals which are separate but complementary came about.

Senator DOMENICI. Is Lockheed's interest basic R. & D., or to produce a commodity or product?

Mr. ORMSBY. Both.

Senator DOMENICI. If we had a full-scale Federal program going and your venture was funded, do you expect any problems with reference to the proprietary interest? Are you worried about that at this point or not?

Mr. ORMSBY. We have the fundamental patent on the lithium-water couple. We have done some development since that time for the military and that work, of course, belongs to the customer.

And so it would be similar to that in previous documents where the efforts are funded by the Government and the rights vested in the Government. We do want to retain our fundamental patent which was done on our own.

Senator DOMENICI. In your negotiating with ERDA, has the question of your retention of the fundamental patent if you complete a project come up? And if so, how is it being treated?

Mr. ORMSBY. It hasn't come up. We submitted the proposal; and it is being reviewed. Obviously, in the negotiation of such an effort or contract, that question will come up. But it hasn't yet, at least that is my understanding.

Mr. GALBRAITH. We have offered to negotiate a mutually acceptable clause and we are not fully aware of what ERDA's posture will be. So we really can't answer the question very well.

Senator DOMENICI. I think it is going to cross all R. & D. efforts in new kinds of energizers for mobility. For example, the problem is rampant throughout the jet propulsion study which claims new automobile engines can be phased in 10 years into part of the fleet.

If you go with the Federal project of the size they are saying, where are the automobile manufacturers and their existing rights? And how do you join them together? What is the finished product? Who owns it? Do you get their cooperation or not, as you move through it? Perhaps you are in a little different area but it permeates it.

In Senate bill 1883, there are provisions for a new prototype automobile? Are you aware of that bill?

Mr. ORMSBY. Generally; yes.

Senator DOMENICI. Is ERDA the appropriate umbrella for all of this research, or does it belong in something like DOT or some other department? Could you express some views on that?

Dr. HOLZER. I clearly cannot, Senator. I believe it would be very presumptuous for me to do so. I would hope that you might pose that question to the Government witnesses which are following us here.

Senator DOMENICI. I assume all of you know enough about the R. & D. process that is going to be needed and that it crosses many spectrums. I also assume you are aware that ERDA is vested with that general power. When we created them, it was to bring unity to the energy field and they have the general authority to involve themselves in mobility R. & D. of the type we are talking about.

Do you think that is a good concept? That we have one major agency evaluating where we ought to be going among the diverse possibilities?

Dr. HOLZER. My personal opinion is that it is. And perhaps—let me express one other thought on this, if I may.

I personally very much like ERDA's approach of involving industrial research and industrial companies in energy endeavors. We at Livermore are not going to produce or sell batteries or other devices. Our interest is to further the rapid and sensible introduction of all energy technology, or as many technologies as we can, into the commercial, industrial market.

And in this sense I am very pleased with the approach ERDA has taken. And it is for this reason that I am personally very enthusiastic and optimistic about a joint endeavor such as the one that we hope to engage in.

Senator DOMENICI. You are aware that it is the AAPS division of ERDA that is involved in this program that we are speaking of? When it was first in EPA and went then to ERDA, it was called AAPS. Is that who you are dealing with?

Dr. HOLZER. We have submitted our proposal to the Energy Storage Division of ERDA.

Senator DOMENICI. If you were to assume that the AAPS division is the principal ERDA department for this whole field we are talking about—alternative engines, electric energizers—would you give us your opinion, based upon the condition we are in in this country, if $10 million is adequate annual funding for such a program?

Dr. HOLZER. I am sorry. I am really unable to answer that question, sir.

Senator DOMENICI. Do either of you have a comment in that regard?

Dr. HOLZER. For our own project, on the order of about $1.5 million for the first year, and a total of roughly—and I am talking now about both Livermore and Lockheed together—of perhaps $15 million over 5 years.

Senator DOMENICI. When you say jointly, is that half each?

Dr. HOLZER. Roughly.

Senator DOMENICI. It would be $7.5 million as the Government's half over the 5 years, more or less?

Dr. HOLZER. Total Federal expenditures of $15 million.

Senator DOMENICI. Do you have an objection on the adequacy of $10 million in this field?

Dr. HOLZER. No; I do not.

Senator DOMENICI. Do any of the other witnesses have such an objection?

Mr. GALBRAITH. Senator, you posed a number of questions which I would like to have the opportunity to offer a couple of observations.

First, to go back just a moment to the proprietary rights issue, I don't anticipate a great deal of difficulty with that being, as a matter of policy; Lockheed's policy is similar to ERDA.

On the issue of organizations, as I understand it, the ERDA philosophy right now, and this is perhaps talking out of school, but an energy storage device such as Lockheed and Livermore have proposed to ERDA would be developed in the energy storage area.

But when it comes time to apply it to a practical automobile, it would go over perhaps to the alternate automotive propulsion area.

On the adequacy of funding issue, I think the Nation is in a situation of trying to catch up in many areas from decades of neglect. And it would not be surprising, then, that in the early phases there will be many things that need to be done which haven't been done. I think the number you cited is probably not an adequate level of funding for the cast-out phase of the Nation's transportation technology.

Senator DOMENICI. Thank you, Mr. Chairman.

Senator MOSS. Thank you very much, gentlemen. We appreciate your testimony.

We now have the Honorable Austin N. Heller, Assistant Administrator for Conservation, Energy Research and Development Administration; and Mr. William E. Stoney, Acting Assistant Secretary for Systems Development and Technology, Department of Transportation, and Dr. Richard L. Strombotne, Chief, Energy and Environmental Division, Department of Transportation.

We will ask Mr. Heller to go first followed by Mr. Stoney.

I reiterate what I stated earlier, we would appreciate it if you would place the full statement in the record and try to summarize or capsulize as best you can.

Mr. Heller?

STATEMENTS OF HON. AUSTIN N. HELLER, ASSISTANT ADMINISTRATOR FOR CONSERVATION, ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION; WILLIAM E. STONEY, ACTING ASSISTANT SECRETARY FOR SYSTEMS DEVELOPMENT AND TECHNOLOGY, DEPARTMENT OF TRANSPORTATION; ACCOMPANIED BY DR. RICHARD L. STROMBOTNE, CHIEF, ENERGY AND ENVIRONMENTAL DIVISION

Mr. HELLER. Mr. Chairman, before I proceed, I would like to introduce my colleagues that are sitting at the table.

On my immediate right is Dr. James Kane who is my Deputy, John Brogan, Acting Director, Division of Transportation Energy Conservation, and on my far right, Dr. George Pezdirtz, in charge of our battery research.

Senator MOSS. We are pleased to have you.

Mr. HELLER. I wish to thank you, Mr. Chairman, for the opportunity to testify on the S. 1632 and H.R. 8800.

My guide for comments on these bills is the President's recent statement concerning the establishment of a new $100 billion Government corporation.

I quote in part:

This energy independence authority is to serve as a catalyst working through American industry and undertaking only those projects which private business cannot undertake alone and which are vitally needed to achieve energy independence for our Nation.

The major thrust of the President's statement conveys a need for dramatic action: crash development and early implementation to attack and eliminate the basic defect of America's present energy system which is—as a Nation we must rely mainly on our least plentiful domestic energy sources, oil and natural gas, and rely least on our most abundant energy resources, namely coal and nuclear power.

This concept coincides with ERDA's plan to meet head on the Nation's critical energy situation. We believe the time to act is now.

I have examined the proposed electric vehicle bills and find that their purpose, also, is in accord with the President's most recent energy statement.

We recognize that transportation uses 25 percent of the total energy consumed in the United States; the automobile uses more than half of the energy consumed by the transportation sector; the transportation sector is virtually 100-percent dependent on petroleum energy.

Clearly these facts cry out for early implementation of improved technologies.

I realize that the automobile industry is applying known energy-saving techniques with great success. In fact, the industry has effected a 13-percent improvement in fuel economy for 1975 models when compared to 1974, and there are reports of over 25-percent improvement in fuel economy on the average for 1976 model year cars as compared to 1974 models.

It is apparent that we need to work in partnership with industry if we wish to achieve new technology that would lead to even more dramatic improvements in fuel economy. For example, the development of gas turbine and Sterling cycle engines would fall into this category. We believe that both of these systems are likely to have higher fuel economy than the internal combustion engine. In addition, both systems are nonsensitive to fuels, both petroleum and nonpetroleum derived.

On the other hand, vehicle propulsion systems that derive their energy from electric power plants offer certain benefits that no other existing or proposed propulsion systems have. The energy source for electric vehicles can be virtually any resource, namely nuclear, coal, geothermal, synthetic fuels, solar, wastes, as well as gas and oil. This opportunity offers the Nation an option to shift from petroleum-based vehicles to a system that can use virtually any nonpetroleum fuel.

Even a partial shift to electric vehicles or its hybrids could result in significant petroleum savings. For example, consider the city of greater St. Louis, Mo., which today has 1 million automobiles, or 1 percent of the Nation's automobile population. This automobile population consumes, on an annual basis, about 19 million barrels of crude oil equivalent. At $11 per barrel, this would equate to a cost of $213

million. If this automobile population of St. Louis were to be changed to a mix of 75 percent ICE's, 5 percent diesels, and 20 percent battery-powered vehicles, the petroleum consumed would be reduced 2.1 million barrels a year and would result in a gross savings of $24 million. The additional coal required for recharging purposes—900,000 tons—would cost about $16 million. Therefore, the net fuel cost savings to the St. Louis consumers would be about $8 million per year. This, of course, would be offset to some extent by the higher life-cycle costs of currently available electric vehicles.

This is but one example of how electrics could impact on petroleum consumption. Our R. & D. program is structured to develop technology that will improve the performance of such vehicles; improve batteries, controls, and other vehicle components.

In my opinion, the proposed bills, if enacted, would mandate a costly and premature program of questionable value. The reasons for this judgment are detailed in the documents which I now ask to be placed in the record.

Senator Moss. It will be placed in the record.

Mr. Heller. For your guidance, I have also summarized a number of key points which reflect my opinion. These may be stated as follows:

Current lead-acid battery technology is adequate for some applications, such as urban delivery operation.

Improvements in lead-acid batteries are required to increase performance and decrease operating costs.

Until the improvements in battery technology occur, it would be premature to support a large and costly demonstration program.

A minimum of 3- to 5-year development program would be required to reduce operating costs and thereby gain public acceptance.

ERDA's basic legislation directs us to be innovative in managing our program while the proposed bill would severely limit opportunities to display this vital characteristic.

In addition, there are inflexible aspects such as the mandate to procure 2,500 vehicles within 15 months—that is the House version—and 5,000 vehicles within 18 months—the Senate version.

In essence, we support the goals of the proposed bills, especially the endorsement of the need for a vigorous effort in research and development on energy storage technologies and vehicle systems and components.

We further agree that demonstrations are desirable to stimulate the interest of the general public but believe that proceeding rapidly with current technology might not achieve the goals that we both seek.

The foregoing summary, I trust, will be of some value in your deliberations.

I would now be delighted to answer questions that you may have.

Senator Moss. Thank you very much. We will have some questions that we will want to ask you.

I think perhaps we will hear first from Mr. Stoney and then we may ask the panel various questions.

Mr. Stoney, would you proceed, sir?

Mr. Stoney. Mr. Chairman, thank you for your invitation to appear and present the views of the DOT on the development and demonstration of electric and hybrid vehicles as proposed by H.R. 8800 and S. 1632, and related issues.

With me today is Dr. Richard L. Strombotne, Chief of the Energy and Environmental Division of my office.

At the chairman's request, I have condensed my testimony somewhat from the handout.

As you know, DOT is interested in all automotive transportation.

The Secretary's recent statement of national transportation policy noted our intention to preserve and maximize the unique contributions of the automobile while striving to increase its energy efficiency, its safety, and its economic and socially responsible use.

The Department has led, or participated in, a number of studies of automobile technology.

It has also sponsored R. & D. involving energy conservation, safety, emissions, costs of automotive transportation, and their interrelationships.

Electric and hybrid vehicles have been considered and investigated by the Department in some of these studies.

Several comments on electric vehicles can be made based on these experiences.

First, the principal barrier to the greater use of electric vehicles is the inadequacy of commercially available electric batteries.

High performance batteries with much greater energy and power densities than possessed by present lead-acid batteries will be needed before electric vehicles can compete with conventional cars.

Second, assuming such batteries can be developed, it is not at all clear that electric vehicles will prove to be significantly more energy-efficient, enviornmentally sound, or cost effective than motor vehicles with spark ignition engines.

Such vehicles will save petroleum when more of the Nation's power generation is converted to coal and nuclear plants.

Third, electric vehicles designed to compete for a significant part of the automobile market should be compared with cars designed for that same market using the advanced technology that is likely to be available when the advanced battery is available.

Among the issues raised by the bills are R. & D. on batteries, Federal support of electric vehicle demonstration, and the safety of electric vehicles.

We support the concept that the Federal Government, through ERDA, should support research and development of batteries for electric vehicles and the development of hybrid powerplants.

These activities are needed as part of the Federal Government's continuing assessment of the benefits of alternative powerplants and the development of options for the future.

But while Federal support of exploratory and advanced development of the batteries and hybrid power plants is appropriate, we believe that actual engineering development for commercial production and use is better left to private industry.

Similarly, we are not convinced Federal sponsorship of electric vehicle demonstrations as described in these bills is desirable at this time.

Considering the inadequacy of available batteries, a demonstration would serve only to highlight the possible benefits.

Also, the timetables specified in S. 1632 and H.R. 8800 for purchase of vehicles and development of criteria may well be too short to count on having improved batteries for the demonstrations.

Finally, with respect to the safety issue, it is our general view that when large numbers of electric vehicles or hybrid vehicles enter the fleet, they should ensure the same occupant safety as is required of conventional vehicles produced in the same year.

The occupants of electric vehicles would be exposed to much the same hazards as occupants of other cars and deserve the same degree of protection.

We share with the sponsors of the bills a desire to develop more energy-efficient, environmentally sound and cost effective vehicles which will be attractive to those who travel by car.

We believe that an ERDA program to develop adequate batteries and certain vehicle components is essential to push forward the electric car option, but ERDA should be allowed flexibility in deciding the timing and extent of a demonstration program.

This completes my testimony. I will be happy to answer any questions you may have.

Senator Moss. Thank you very much, Mr. Stoney.

Mr. Heller, you state in your testimony that:

> We support the goals of the proposed bills, especially the endorsement of the need for vigorous effort in research and development on energy storage technology and vehicle systems and components.

Would you tell us if you support the funding levels directed at research and development authorized in S. 1632 or H.R. 8800? In other words are these funding levels, in your opinion, sufficient for ERDA to carry out adequate R. & D. in the area of battery storage technology and electric vehicle systems?

Mr. Heller. Mr. Chairman, in response to your questions, we estimate that for a 5-year program which would include the necessary research and development, and test marketing of the vehicle, about $250 million would be required; about $150 million for battery development, $70 million for components, and about $75 million for test marketing.

What I am really saying is that the estimated cost for the undertaking is somewhat above what has been suggested.

Senator Moss. So the amount suggested in the bill is too low?

Mr. Heller. In either bill, yes.

Senator Moss. In addition to battery research, where else should a Federal R. & D. program on electric and hybrid vehicles focus its effort?

Mr. Heller. One aspect you may recall is the item of test marketing a battery-operated vehicle. And therein we would find it important for us to determine how the structure would respond to the introduction of a battery-powered vehicle. And this would help us. One has to know very much what the system is going to be to maximize the benefits of R. & D.; how it is going to be laid out within an urban community, what one does with the batteries themselves on recharging and replacement.

These are some of the factors that come out through the test marketing, become a functional part of the design and implementation of research efforts.

Senator Moss. You stated that demonstrations are desirable to stimulate the interest of the public, but that you question the inflexibility of the programs mandated by H.R. 8800 and S. 1632.

Would you support this program if there was greater flexibility built into the timing and size of purchases mandated in the demonstration program section?

Mr. HELLER. I would support it.

Senator MOSS. Could you give us some idea of what you believe would be the proper timing of electric vehicle demonstration programs and what level of purchase would be adequate?

Mr. HELLER. I would like to respond this way, Mr. Chairman: The first thing that I would do, if I were given the opportunity, would be to hire the best professional help I could get in the merchandising area, particularly to assist us as to how best to put the pieces together and test market the vehicle. I would seek out the best professional advice also with respect to the R. & D. effort, and that would be a functional part of system evaluation, so I am not in a position to give you a precise answer to your question at this time.

Senator MOSS. Dr. Haywood of MIT stated that the electric vehicle demonstration program should focus on fleet operations such as urban delivery vehicles, buses or rental vehicles for use within restricted areas, rather than on private passenger vehicles.

What is your opinion of those views?

Mr. HELLER. I think it is a valid suggestion and certainly would be one of the areas that would be considered part of the program.

Senator MOSS. So you believe, the electric vehicle is a specialized vehicle, in a sense, because of its more limited range and performance characteristics, at least currently not up to the combustion engine, and you think testing it in a controlled manner is better than just trying to sprinkle it around among general users; is that correct?

Mr. HELLER. I think I would answer you this way: It seems to me that initially with regard to the opportunities to evaluate the introduction of electric vehicles into the overall system—perhaps much can be gained by taking the first step within the controlled system.

Senator MOSS. I wonder if you could give us your views on the utility of Federal R. & D. in the area of hybrid vehicles? Your statement focuses on electric vehicles; and I don't believe it touches on the hybrid issue.

Mr. HELLER. I am acquainted with some of the work going on in the hybrid area. But I would like to ask a colleague of mine to respond in more detail.

Senator MOSS. All right.

Senator Stevenson is going to replace me because I have to go. He will carry on now.

Mr. HELLER. I would like to ask John Brogan to assist me and answer the question that Senator Moss has presented.

Senator STEVENSON [presiding]. By all means.

Mr. BROGAN. We are very interested in many of the concepts that have been proposed by small, high technology groups to promote the development of hybrid vehicles. In the past we found that the fundamental problems with these hybrid systems is that they tend to be heavy and bulky, have rather complex control systems, and in their present state of development are not competitive in fuel economy with the conventional engine.

However, a number of new ideas and new versions of hybrids have been presented to us since ERDA came into existence, and we fully intend to explore the better ideas.

Senator DOMENICI. I'm going to have to leave very shortly. I was interested in Dr. Stephenson's testimony. I have read it and I'll talk with him later.

I assume some of you have seen Jet Propulsion Lab's studies as it concerns this issue and their concept of R. & D. on engines. Mr. Heller, you read a general statement with reference to the President's proposed $100 billion energy bill. Do you have any reason to believe that the legislation as proposed is broad enough to include energy conservation techniques, or is it limited to the development of new energy resources?

Mr. HELLER. It's my interpretation that the bill itself would allow the flexibility for the development of technologies that one might say would be on the demand side. I don't recall that the limiting factor you mentioned was addressed to that aspect.

Senator DOMENICI. Did you quote his goal or objective to indicate to us that the corporation concept that he is speaking of might be a better approach than to expand upon ERDA or some other existing agency in a more meaningful manner than we have? Are you offering the other as an alternative to the present selection process that we are going through and fighting over as to where the R. & D. money ought to go?

Mr. HELLER. My purpose was to direct the attention of the committee to the great concern with respect to the development of technologies that would allow us to meet our objectives as quickly as we are able to meet them effectively. And I wanted to point out that I thought what we were discussing today would fit into that category.

Senator DOMENICI. My next question is directed to the ERDA people here. It appears to me as we go through this process of finding areas for demonstration—we have the electric car today and we have a whole new prototype in another bill that you all are supposed to work on—the question is whether ERDA is in a position to prepare an overall game plan, evaluating the various potential R. & D. thrusts and their goals? Do they have the mandate that they'll present such a thing to the Congress, or are they picking and choosing based upon their own decisionmaking as to which projects they are going to fund?

For example, if we had $300 million to spend in this general area, we don't have anyone, really, analyzing the alternatives within it, whether it be this proposal or whether it be three or four different other approaches. Nobody has put the alternatives down in relative degrees of urgency and possible success based on America's needs with any kind of structure around them in terms of dollars, have they?

Mr. HELLER. In my understanding, one report has attempted to come forward with some of the opportunities. As I recall the thrust, they actually selected two systems that they thought should be supported on a priority basis, that is, the Sterling and the turbine engines.

Senator DOMENICI. I wonder if ERDA is doing anything like that on a national scale.

Mr. HELLER. Certainly, I can speak from my own vantage point, that we already have begun to examine where our priority ought to

be placed. And I believe this is a very important assignment, that we do select those priorities, those projects that are likely to give us the payoff as soon as possible with the least cost.

Senator DOMENICI. You therefore consider that to be within the present mandate of ERDA in this area?

Mr. HELLER. I certainly do.

Senator DOMENICI. Is it being worked on?

Mr. HELLER. We have already begun.

Senator DOMENICI. What is the status of that work?

Mr. HELLER. I have discussed the matter with my staff in terms of the projects they are asking to be funded; and I asked them to indicate to me just what the savings ought to be in 1976, 1977, 1978 and so forth.

Senator DOMENICI. Who are you using in an effort to develop this kind of position or posture for ERDA?

Mr. HELLER. At the present time, a review is inhouse. I'm planning to have a policy planning group on my staff as soon as I can. And once I do that, the decision will be made to where we go on the outside to assist us in making the determination.

Senator DOMENICI. Is it fair to assume that you need both private and public sector advisors on that?

Mr. HELLER. No question about it.

Senator DOMENICI. How long do you think it will be before you have set up that kind of apparatus in ERDA?

Mr. HELLER. My hope is that I'll be on stream in a month's time.

Senator DOMENICI. At the present time, with the small amount of money you have to spend, you have all kinds of projects being proposed by inventors in industry and otherwise, and you're just having to do the best you can to see what you ought to be doing at this point in time. Is that right?

Mr. HELLER. We are trying to develop an arrangement that will give us the best opportunity with the resources at hand.

Senator DOMENICI. The Department of Transportation said that the kind of proposal that is encompassed in the legislation before us is best handled by the private sector. I think you made that remark.

Mr. STONEY. I mentioned that the engineering development should be done in the private sector. But the R. & D. should be done in the public sector, when industry is unable or unwilling. And I think, in this case, at the present time that is the situation.

So the research that needs to be done in this area on batteries, and components, has to be pushed forward, or else it won't be done.

Senator DOMENICI. In that respect, would it not be rather important that the private sector be involved in the entire process or you will have Government-built prototypes, but no one to sell them to the people.

Mr. STONEY. That is correct, and any program of R. & D. should be worked out with the close participation of industry. In fact, most of the money is spent in industry. It is available to all of industry by means of appropriate dissemination of the results. So industry is involved in it. Their comments are very important. And much of the work is actually done by them.

Senator DOMENICI. I don't want to be construed to be in opposition of the subject bill. I hope you don't consider me to be that, but I want

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to ask some questions about whether or not it does certain things. In light of that last remark, could you comment on whether the bills before us do that? Do they bring together the private and public parts of this as we go through, or does it tend to disassociate one from the other.

Mr. STONEY. My comments in the negative on the bills were just in two points. One is that the time schedule should be left flexible for ERDA on the demonstration program, the time schedule should be flexible for ERDA to make the decision at the appropriate time. The state of the art of the batteries today is not adequate to start a demonstration program with that type of battery, in my opinion.

Senator DOMENICI. Thank you very much, Mr. Chairman.

Senator STEVENSON. Mr. Stoney, you said the timing of the demonstration program may be too short. What timing would be adequate?

Mr. STONEY. What I would prefer to see is that the program be planned based on decision events, rather than times.

Those decision events being something like: The battery will be available by such and such a time and can be used for the program, now we start the demonstration program. You can't say right at this stage, when that battery will be available.

So I would suggest that the bill be changed to make some decision milestones based on events rather than on any particular dates.

This is the flexibility that ERDA needs, that is what I am referring to.

Senator STEVENSON. Are you suggesting there ought to be certain stages that ought to be established?

Mr. STONEY. Yes. "You will be directed to start a demonstration program when you can prove so and so." I think Mr. Heller should answer that.

Senator STEVENSON. How would you answer that, Mr. Heller?

Mr. HELLER. Actually, the question was posed prior, and what I said was that we would seek out the best people from the standpoint of merchandising and we would seek out the best scientific people available to us. And we would use that thrust to establish our goals and our overall program. That is precisely what I have to say with respect to flexibility.

Senator STEVENSON. Gentlemen, I am new to this subject so I am going to have to rely on Staff for a few questions. There are a few more answers that we want to get into the record, and there is not much time.

Mr. Heller, in your testimony you state that the proposed bill would severely limit ERDA's opportunities to display innovative management of the electric vehicle program. Would you elaborate on that?

Mr. HELLER. The mandate is that we ought to procure 5,000 vehicles within 18 months—which is the Senate proposal—and that presupposes that we know all there is to know about the technology, that we know all there is to know about the infrastructure, and that we know precisely that the market can produce the 5,000 vehicles in time, and that 5,000 is the precise number we need to demonstrate the feasibility of introducing an electric vehicle into the marketplace.

My point is that I don't feel this is the case.

Senator STEVENSON. How would a program be structured under ERDA in order to maximize ERDA's management capacity for innovation?

Mr. HELLER. Given the flexibility, it certainly would.

For example, we certainly would like to know what effect the introduction of an electric vehicle would have on the Nation's infrastructure and what is the availability of recharging, the manner in which the batteries will be either removed or replaced, the response time on the part of those who are going to use the vehicle. As to how many we would need to make a determination, it would seem to me that would take some exploration and some study as we went along.

In other words, when we begin to test the market, it would be on a small scale, get the feedback and then expand testing in order to achieve the results we are seeking.

It is a little difficult for me to accept the precise numbers as set down. I am not entirely sure whether the number that is set down would allow us to achieve our objectives, whether we would be unable to achieve the objectives or whether we could even effectively use the number of vehicles. I am not in a position to say. That is why I am suggesting flexibility, so we can get there as quickly as we can at the least cost.

Senator STEVENSON. Should there be a separate allocation of funds for research and development and another allocation for the demonstration program?

Mr. HELLER. I don't think so. I think it should be part and parcel. We are dealing with the whole system, and I would like to see the system evaluated as an entity, not in separate parts.

Senator STEVENSON. Mr. Heller, what are your views on the current and future applicability of safety standards?

Mr. Heller, I would like to defer to my colleague, who has an expertise in this area, Mr. Stoney, from the Department of Transportation.

Mr. STONEY. We believe that these vehicles used in the demonstration programs should meet the same motor vehicle safety requirements that other vehicles do for that period of time when they are built. We think this is important because to make a good comparison between a lightweight, flimsy vehicle that doesn't have the safety features of the automobile that it is to compete against, I think, would be improper. The occupants of the electric vehicle should have the same safety features as all other types of vehicles. With regard to safety itself, an electric vehicle can be built with the same structure, the same safety structure as any other vehicle. Comparing the differences between the two in safety, the only differences might be the safety problems with batteries versus safety problems with gasoline. I believe gasoline is probably less safe than the proposed batteries.

Senator STEVENSON. Is there any need for safety exemptions during the demonstration stage?

Mr. STONEY. It would be a mistake during that stage to have the exemptions. I see no reason for them either.

Senator STEVENSON. Mr. Stoney, in Dr. Heller's testimony, he states that:

> Electric vehicles offer certain benefits that no other existing propulsion systems have. For example, the ability to rely on virtually any energy resource to provide a source of power.

Do you agree generally with that proposition?

Mr. STONEY. Yes. As we move toward more and more electrification of the Nation, as a result of "Project Independence" and conserving oil, petroleum for long-haul aircraft, I think we will need a vehicle and many other kinds of vehicles that will use electricity in one way or another.

Senator STEVENSON. In your statement, you support Federal R. & D. in the area of battery research. What other areas do you believe the Federal Government should institute a program in order to improve electric vehicles?

Mr. STONEY. I also mentioned the components and the control devices and probably the propulsion system itself. However, I am not an expert in those areas. But all the components should be developed that are needed to make an overall system.

Senator STEVENSON. Is the loan guarantee provision in these bills useful or is any other financial assistance desirable?

Mr. STONEY. Guarantees to industry are not always enough to cause an industry to move into a field like this, in many cases. The risks are still there for him, in spite of the guarantee. And the entrepeneur is risking his business.

So I think the government-sponsored R. & D. in these areas where the industry can't afford the risk are needed as well as loan guarantees.

Senator STEVENSON. Dr. Haywood has suggested that the demonstration programs focus on fleet operations, such as urban delivery vehicles, buses or rental vehicles for use in restricted zones. If the demonstration program were to be focused in these areas and so-called "second car" applications, would you then support such a demonstration program?

Mr. STONEY. Would you repeat the question, please?

Senator STEVENSON. Dr. Haywood of MIT has suggested that the demonstration program focus on fleet operations, such as urban delivery vehicles, buses, rental vehicles for use within restricted zones, rather than general purpose vehicles. And the question is whether you would support such a focused Federal demonstration program?

Mr. STONEY. I think Professor Haywood is looking at the demonstration program to obtain technical knowledge. And that is why he believes in the demonstration program in a fleet operation, where you have some control of maintenance and reliability, and you have a proper support structure for the demonstration program. People that are interested in demonstration programs from a test marketing point of view would like to have as broad a distribution of vehicles as they might have, just so they can get more and more marketing information. The two types of programs are not necessarily compatible. I would prefer, myself, to have a closely controlled demonstration program with all the vehicles in an area that has all types of weather, for instance, and be sure the reliability problems that people perceive are not due to something like—that hasn't anything to do with the electric part of propulsion, but might have something to do with the windshield wiper.

I think it would be a mistake to send automobiles, limited numbers here, all over the country with statistics that would show in the newspapers, with the broken down cars that took three months to get spare parts, would just kill the program.

Senator STEVENSON. Thank you, gentlemen. That is all the questions we have. We appreciate your help and we thank you.

Mr. HELLER. I want to call your attention to a report we just received. We would like to make it available to you. We think you will find the information helpful.

Senator STEVENSON. It will be made a part of the record.

Our next witnesses are Dr. Rhoads Stephenson, Jet Propulsion Laboratory, California Institute of Technology, and Mr. Domenic Borello, president, Die Mesh Corp.

STATEMENT OF R. RHOADS STEPHENSON, JET PROPULSION LABORATORY, CALIFORNIA INSTITUTE OF TECHNOLOGY; ACCOMPANIED BY HOWARD VIVIAN

Mr. STEPHENSON. Mr. Chairman, it is indeed an honor to be asked to testify before your committee. I am Dr. R. Rhoads Stephenson, manager of the systems analysis section at the Caltech Jet Propulsion Laboratory, and principal investigator of the recently-completed automobile power systems evaluation study. Some of you may have seen a copy of our two-volume report entitled "Should we have a New Engine? An Automobile Power Systems Evaluation." What I will be saying today will be based upon that report.

With me today is Mr. Howard Vivian, also of the Jet Propulsion Laboratory, to whom I may refer certain technical questions with your permission, Mr. Chairman.

Electric vehicles are being considered here today presumably because of an expected favorable impact on energy consumption and emissions. The study we recently completed considered a wide variety of alternative power systems for the automobile. Initially I would like to describe the approach and findings of that study to put in context my comments on electric and hybrid vehicles.

At the outset I wish to describe the approach we used in this study. First of all, we emphasized technologies which could be in significant production during the decade of 1980–90. By significant production we mean 10 to 30 percent of sales (or about 1 to 3 million vehicles per year) before the end of the decade, and the potential to grow to a significantly higher percentage of the market. This lower bound was established because it was important to look at changes which would make a significant difference at the national level.

Another key aspect of the study was the Otto-Engine-Equivalent vehicle concept. We did not want to be vulnerable to the charge that we created (on paper, of course) a vehicle which the American people would not buy. To that end, we studied the characteristics of 1974–75 cars as a base point, and defined six size classes of cars covering the span from a "mini" (1,600 pound curb weight) to a large luxury car of 5,000 pounds. In each of these car size classes we attempted to hold constant those parameters which are most visible to the consumer such as; interior size and accommodations, acceleration capability, accessories, ride and handling characteristics, durability, noise levels, emissions targets, and driving range.

We systematically evaluated various alternative power systems by figuratively removing the conventional spark ignition (Otto cycle) engine and "installing" the alternate engine. The vehicle weight was

carefully adjusted to reflect the changed power system weight and power. We also adjusted the peak horsepower of the alternate powerplant to provide the same acceleration capability as the baseline Otto-engine powered vehicle. Finally, the fuel tank was resized to give equal driving range.

When this process is completed, one is left with a vehicle powered by an alternate power system which is to a large extent functionally equivalent to a conventional car in the eyes of the consumer. Alternate-engine cars of the same size class will, in general, have a different installed horsepower and curb weight than the baseline vehicle.

Our evaluation was focused primarily on the benefits of an alternate engine to the Nation in terms of improved air quality and reduced fuel consumption. We also considered the availability of the necessary materials of construction, the requisite capital investment and changeover time, and the impact, if any, on vehicle and highway safety.

Within the framework described above we evaluated seven alternative automobile power systems against a moving baseline of the conventional Otto-cycle engine and its likely improvements. The generic types of power systems analyzed were the Uniform-charge Otto-cycle, Stratified-charge Otto, Diesel, Rankine (steam), Brayton (gas turbine), Stirling, Electric, and Hybrid. These systems were evaluated at consistent levels of technology described as "Present" (meaning presently existing either on an engine test stand, a demonstration vehicle, or in mass-production), "Mature," and "Advanced." The "Mature" level of technology was the primary basis for comparison and represents a mass-producible power system resulting from an intensive development program based on known technology (in terms of pressures, temperatures, and materials).

After examining all of these major categories of power systems, we recommend the following strategy:

1. Begin immediately the rapid introduction of design changes to the car itself which can significantly reduce fuel consumption, independent of the kind of engine used. Fuel consumption reductions of 25 to 45 percent are possible depending on car size.
2. Concurrently, accelerate and direct the development of two particularly promising alternate engines—the Brayton and Stirling engines, with introduction targeted for 1985 or sooner. Fuel consumption reductions of 25 to 32 percent can be achieved with these technologies while at the same time eliminating the automobile as a major source of air pollution.
3. In the interim, press the development of the conventional Otto engine to its limits.
4. Intensify research in high-temperature structural ceramics and advanced batteries.

As discussed in the report, the recommended parallel Brayton and Stirling development program is estimated to cost about $150 million per year for a total of about $1 billion over the next 5 to 7 years.

Relative to electric vehicles, our specific findings are:

1. A major breakthrough in battery technology is required to make electric vehicles competitive with general-purpose heat-engine-powered vehicles. In particular, with current or near-term projected batteries it was not possible to configure an Otto-engine-equivalent vehicle in terms of sustained load, range between recharges, and recharge time.

2. The energy efficiency of present, lead-acid, limited-range electric vehicles (at the electric generating station, on a miles driven per barrel of crude oil basis) may be slightly higher (approximately 10 percent) than a car powered with the Mature Otto-cycle engine. Advanced batteries are not expected to dramatically increase the energy efficiency.

3. Electric cars are not pollution-free if their primary source of power is a combustion-type generating station. In particular, the emissions of NO_x, sulfur dioxide, and particulates may be comparable to the Mature Otto-cycle powered car on a per-mile basis.

4. The electric vehicle is an attractive long-term option for the Nation in terms of its multifuel capability and its low emissions potential (if the primary source is environmentally clean). Its primary energy source could be from fission, fusion, solar, wind, or geothermal power as well as from fossil fuels.

We feel that the best way to work toward the goal of a general purpose electric vehicle as a long-term option is to concentrate on battery research and development. A greatly intensified program is warranted including a large amount of parallel work on different battery concepts by many different laboratories. These multiple approaches will increase the probability of a successful outcome. A sizable component of fundamental, as well as applied, research should be included in the program. The objectives of this battery R. & D. program should include, in addition to the desire for high energy and power density, the following attributes: high efficiency, extended cycle life under deep-discharge conditions, long-service life, rapid recharge, low self-discharge losses, acceptable cost, use of reasonably abundant materials, environmentally acceptable system, and adequate safety.

Other desirable improvements in electric vehicles are related to the motor, controller, and the integration of the vehicle system. These more straightforward development problems should not detract from the major emphasis on the battery R. & D. Solving these nonbattery problems now will not hasten the day of the general-purpose electric vehicle, but it could result in some near-term benefits for electric cars used in specialty applications. Such a development program would probably require a few test vehicles.

We do not see a significant technological benefit from the 2,500 to 5,000 car fleets proposed in the legislation currently pending before this committee. The time scales (freeze dates) involved are much too short to allow adequate systems development and could detract emphasis from the necessary battery program.

I would now like to make a few comments about hybrid vehicles. By a hybrid I mean a vehicle with a heat engine (we considered only the Otto-cycle engine since it has the most to gain) with some sort of storage element (battery or flywheel) to allow it to operate at a more efficient power setting (when the engine is operating). Since it has a heat engine, it looks like any other liquid-fueled vehicle from a fuel supply point of view. Thus, it is a generically different vehicle from an electric vehicle.

Our findings relative to hybrids are:

1. If sustained acceleration/hill-climbing capability is sacrificed, a hybrid-powered vehicle can be otherwise performance-competitive with a heat-engine powered vehicle.

2. The best heat engine/electric hybrid configuration (the so-called parallel, on-off type) may achieve up to 20 percent higher fuel economy that a comparable acceleration Otto-engine-powered car. However, fuel economy gains almost as large may be obtainable for conventional Otto-engine-powered cars through the use of a continuously variable transmission alone.

3. The hybrid's heat engine emissions are not sufficiently lower to significantly simplify its emission controls.

4. The purchase price and maintenance costs are estimated to be sufficiently higher than for a conventional automobile that one would not expect to break even on a life cycle cost basis unless the price of gasoline approaches $2 per gallon.

For the above reasons we conclude that hybrid vehicles are not an attractive option for development.

Let me reiterate the major finding of our study; that the Brayton and Stirling heat engines offer the most potential in the medium term for payoffs in terms of clean air and reduced automotive fuel consumption. The general purpose electric vehicle should be considered a long-term option for the 1990 period or beyond.

Mr. Chairman, I would like to express my appreciation to you and the committee for this opportunity to present my views on a critical subject that is of vital importance to the Nation and demands urgent attention. I will be happy to elaborate on any of these points and answer your questions.

Senator STEVENSON. Thank you, Dr. Stephenson.

I think we will proceed next with Mr. Borello.

Mr. Borello, would you please proceed and also, if it is possible, would you please summarize.

STATEMENT OF DOMENIC BORELLO, PRESIDENT, DIE MESH CORP.

Mr. BORELLO. I am going to summarize but I want the full statement in the record.

Senator STEVENSON. The full statement will be included in the record.

Mr. BORELLO. Mr. Chairman, as president of Die Mesh Corp., I appreciate the opportunity to testify as to the feasibility and future of the electric vehicle.

For the past 6 years, the Die Mesh Corp. has had several electric passenger vehicles on the road continuously. We have logged a total of approximately 40,000 pollution-free miles under urban short-range driving conditions. All of our electric vehicles have been converted from existing internal combustion vehicles, weighing approximately 2,600 pounds, using lead cell batteries and employing regular 110 volt household current with an onboard charger. Therefore, the same safety features that existed before our conversions also exist thereafter.

Further, we have employed our own patented electrodrive system in these vehicles, consisting of multiple motors and separate "battery packs" arranged to yield the maximum use of the electrical fuel. I personally drive one of our electric vehicles to and from work each morning. Thereafter, during the day it is driven by certain employees

of our company to run errands in and about the town of Pelham. This not only gives us continuous feedback as to how the vehicle performs under all normal driving conditions, but also is a source of education concerning the use of electric vehicles for our local residents.

Through our continued use of electric vehicles, we have now obtained sufficient data concerning the feasibility of using electricity in a vehicle and also maintaining the safety features of the present internal combustion vehicle. Consequently, we have had preliminary designs for our electric passenger vehicles prepared. These electric vehicles of our own design will embody all of the safety features of the conventional internal combustion vehicle.

However, it must be realized that it is absolutely essential that the electric vehicle have its own design and not be a mere conversion. This is due to the fact that the electric fuel is different and therefore requires a different location and a different method of feeding the fuel to the electric motors, controls and onboard charger. It would be just as impossible and impractical to try to convert an electric vehicle into an internal combustion vehicle.

Concerning the lead-cell batteries that are presently being sold for use in electric vehicles, these batteries require no further technological advancements in order to satisfy the requirements of this bill. We have concluded that the battery manufacturers have been unjustly bearing the blame and responsibility for the electric vehicle's lack of advancement. They are neither "the hero" nor "the villian" of electric-vehicle progress.

In our experience, we have found that a few simple improvements in the current physical makeup of the lead-cell battery will make it even more reliable and adaptable for an electric vehicle. As an example, the following items of a lead-cell battery could be greatly improved:

The terminals of the battery that are in essence the link between the fuel supply and the motor, the plate grids inside the battery, additional fittings on the tops of the batteries to provide for automatic refilling, and, finally, each battery should be given a more thorough inspection so that a realistic guarantee can be given by the manufacturer.

An analogy that can be made concerning the improvement of batteries in relation to the electric vehicle can be drawn by observing the advancement of the internal combustion engine from its beginning. Advancement in internal combustion engines came by improving the motor and the manner in which it used the fuel, and not by improving the fuel.

The ultimate goal of this bill should be to place technically qualified small companies, such as Die Mesh Corp., that have had on-the-road experience with electric vehicles over the past years, in full production. Consequently, when the project under this bill is completed, these companies will be fully capable of continuing the mass production of electric vehicles to meet the consumer demand, which should be substantial by the time this program is completed.

Fossil fuels are rapidly becoming "past history," as did the horse and buggy upon the dawning of the gas engine. Electricity, and not fossil fuel, is the energy of the future; whether it be solar energy, atomic energy, hydroelectric energy, or any of the other more sophisti-

cated forms of producing electrical energy that our Government is presently working on. To date, all of the tools that man has developed and is using in his history require electrical energy as their prime mover. Therefore, electricity should now be considered our main fuel, which is capable of easy transport to every person in this country by a simple wire.

The electric motor as presently made is suitable to drive an electric vehicle. However, it was never actually designed for the purpose of powering an electric vehicle. With this realization in mind, the Die Mesh Corp. did, 6 years ago, begin research into finding the best use of an electric vehicle. From this evolved our patented "Multimotor Electro-Drive System." Through this research, we also designed and patented a "Variable Speed Drive" to replace the existing transmission. Thereafter, we designed and patented a "Variable Speed Electric Motor" as an advancement of our "Multimotor Electro-Drive System."

Due to all of our research and development experience with electric passenger vehicles and motors, we are proud at this time to announce our latest invention: "The Modularized Electric Motor." This innovation is a complete departure from the prior art in electric motors. And, this motor has nine advantages over existing motors:

The first and foremost advantage of this new motor is that it is expected to draw only 25 percent less current than the motors in use today. It consists of 50 percent less parts than the motors in use today. It removes 20 substantial problems which beset the present-day motors. It is 33⅓-percent lighter. The coils are water cooled so that it cannot overheat. The water that cools the coils can be used for heating the cabin of the vehicle.

The current draw for this new motor always remains constant, and does not fluctuate with the load. It can be manufactured by the average production lineman, substantially reducing the cost. It can be repaired by the average automobile mechanic by using the spare parts, modularized concept. Each and every part of this new motor is a separate component, so that it can be easily taken apart and replaced.

We would like to submit at this time, to you, five copies of the "Disclosure Document" [1] filed by our company with the U.S. Patent Office which will more fully explain this new motor.

In summary, the successful operation of this inventive motor is due, in part, to the fact that the forces that are capable of being generated between a magnetic field and magnetic material are of a considerable extent, as evidenced by the ability of an electromagnet to lift tremendous weights with a minimum amount of electrical power. This theoretical performance, however, is not properly utilized in a conventional motor because of the movement of a conventional armature in a passing relation to the field. On the other hand, in our new motor the typical magnetic segment is drawn directly into the magnetic field of the coil.

I would also like to point out at this time that the same advantages that apply to this new invention of ours as a motor also apply to it as a generator.

[1] See p. 157.

To all of the overly critical voices that have been quick to judge us, I can only say that it is unfair for them to judge this young industry when it is in its infancy, without giving it the same chance that was given the internal combustion vehicle. You cannot use the same standards for an electric vehicle that are now applied to the internal combustion engine, which, I might add, began with a crank for a starter, candles for headlights, a tiller for a steering wheel, and a top speed of 20 miles per hour.

All of the advancements we have made have only come because we have been involved with actually making electric vehicles. This demonstrates that advancements and progress, which may seem hopeless in the beginning of a project, become realities if one is willing to work for them. With the aid of this bill, we feel that this is only the beginning.

Mr. Chairman, I would like to compliment you and your colleagues for bringing this bill forward and for allowing us to participate in these hearings.

Senator STEVENSON. Thank you, Mr. Borello.

The Energy Laboratory of MIT has issued a report which states, and I quote:

> An electric vehicle does not emit air pollutants, but does cause an increase in load and thus, emissions from the power plant which was a source of electricity for its battery. Thus, nitrogen oxide, carbon monoxide and hydrocarbons on the street are traded for nitrogen oxide, sulfur dioxide, particulates, and heat, or radiation and heat, at the power plant.

It sounds like a trade-off; one source of pollution for another. What is the net benefit? What is your reaction to that statement?

Mr. BORELLO. I think when they made that study they failed to include an important observation, and that is if you have a unit that is producing energy in one location, the ability to maintain the pollutants is much easier. I am saying, in other words, you can control the pollutants in one location much easier than you can—just look at any highway and try to figure out how to hold that stuff down. It becomes an impossible task. It is much simpler at one location.

Senator STEVENSON. That leads me to another question:

A report for EPA entitled "Impact of Future Use of Electric Cars in the Los Angeles Region" states:

> Electric cars can be nearly pollution free. But as shown in figure 1.5, a 90-percent reduction of conventional auto exhaust emissions required by existing legislation in this decade will dramatically reduce total vehicular emissions of air pollutants, and make cars a minor rather than major contributor to total emissions. Under these circumstances, air pollution will no longer be a problem in Los Angeles, and even extensive electric car use will have little further effect.

Mr. BORELLO. It is probably correct. But does that research also disclose where they are going to find the additional oil?

Senator STEVENSON. You are conceding then that as far as pollution is concerned, there is that trade-off?

Mr. BORELLO. Well, I don't know. I have been involved in some antipollution devices and they all seem to have problems. Many of them prove to be just in the reverse of what they should have done in the beginning.

Senator STEVENSON. You are referring to pollution devices for automobile emissions as opposed to pollution devices for generating plants.

Mr. BORELLO. I don't know too much about the pollution devices for generating plants; but I feel it should be done in one place, one location. In a sense, I think they need to continue to find ways to correct the problem.

Senator STEVENSON. When you use electricity, you waste a lot of energy in the distribution from the generating plant. What it does do is that it permits the use of additional sources of energy. We don't have to rely exclusively on oil or natural gas. We can turn to the nuclear sources.

Mr. BORELLO. One of the problems here is that the electric car hasn't been completely developed. It is in a state now where I can go to work in the morning in the car on a highway and keep a speed of about 45 miles per hour, get back home, charge the car and go along very nicely. But, however, what we are talking about today is premature. We are saying the current you use to drive the electric car will remain constant for the next 200 years; and that is not true; that new motor, new design, is completely different.

The motor hasn't been touched for 145 years. Now, I can't believe that the technology of anything can stand still for that long. There are many areas where it could be developed in electricity, but we don't have them right now. If we start now we will eventually get out of this dilemma of spending billions of dollars trying to keep peace just to get oil.

Senator STEVENSON. I should have asked this question of Mr. Heller earlier; but I will ask you now:

Is there any effort to avail ourselves of the research being conducted in other countries? What are the Japanese, for example who are far more dependent on foreign sources of oil—doing in regard to electric battery research?

Mr. BORELLO. Absolutely. As a matter of fact, they have made grants similar to the ones being proposed right now; and they have improved their position in electric motors.

Dr. STEPHENSON. I believe the people at ERDA are aware of their efforts and have managed to keep abreast of the developments over there.

Senator STEVENSON. The Staff tells me that the Japanese do have a research program and that there is some sharing of information with the Japanese; but there seems to be a lot of work that needs to be carried out in these countries in order to share this information. I see there is not even a means to translate——

Mr. BORELLO. It is difficult for ERDA to evaluate all of this as I suppose it is the Japanese. But I don't think all of the information and all the technologies are arranged and collected by either the Japanese Government or the U.S. Government. It think it is laying there just waiting to come out. And I think if you do pass the bill, you are going to find a lot of it.

Senator STEVENSON. Dr. Stephenson, your statement seems to assume that the objective is to replace the traditional automobile with electric vehicles. Shouldn't the objective really be the second automobile, the special applications for this vehicle, as opposed to the general purpose automobile or vehicle? Your objective isn't really a replacement; is it?

Dr. STEPHENSON. We looked at the possibility for second cars; and that would certainly be a first application. But we emphasized significant changes in the automobile fleet in order to make a difference to the national air quality and national fuel consumption picture. A few thousand or tens of thousands of electric vehicles may be quite useful in special applications, but they are not going to make a significant difference in the national energy or environmental problems.

If you want to save energy, you must talk about millions of vehicles per year.

Senator STEVENSON. We are probably consuming more energy, I suspect, of that sort.

Dr. STEPHENSON. Probably.

Senator STEVENSON. You are going to use more energy with these electric vehicles when you rely on an inefficient electric distribution system.

Dr. STEPHENSON. There is some uncertainty in the energy consumption numbers resulting from our analysis. The energy consumption of electric vehicles per mile may turn out to be slightly less or better than with an Otto-cycle engine (including the distribution losses). Our best estimate was about 10 percent better for the electric based on crude oil input.

I might add that I think the long-term question is whether you want to have a car that is powered with liquid fuel or an electric vehicle you can plug into the wall at night. In the long term if we assume petroleum is in short supply or totally exhausted, it is possible to use coal to make liquid fuel or to burn it and make electricity.

It is also possible to make liquid fuel from nuclear power, water, and air, which are renewable resources. The long-term trade-offs of liquid fuel versus electricity haven't been made.

I therefore think it is in the Nation's interest to have an all-electric option.

Senator STEVENSON. I have run out of time. We do have some more questions. But with your permission, we will have to submit them to you in writing.

Mr. BORELLO. I wonder if I can just add something:

All the figures that have been collected as to what the electric car can do are only based upon what you are presently looking at. You don't know what is going to happen when all these different technologies come together. So that it is really not proper to say that the electric car does this or the electric car does that, not until ERDA completes its study, gets sufficient data to say, well, at the end of a year's period, or 2 years, this is what electric cars will do and this is what we say in the future, because, as I said before, we have a motor that will use 25 percent of the amount of current presently used in electric motors. And I think that is a significant advance. It is a complete departure from the present state of the art. Right there alone, that is something that almost says, why are we worried about the battery. Let's take a look at some of the other things.

I have to agree in one sense, and that is, I feel these cars will be complete if ERDA gives us some funds to come up with some nice-looking cars. And that is when you should be looking at how much current and so on. I think you should use some of the information we have given you.

Senator STEVENSON. Thank you very much, gentlemen.
[The statement and articles referred to follow:]

STATEMENT OF DOMENIC BORELLO, PRESIDENT, DIE MESH CORP.

Mr. Chairman, as President of Die Mesh Corporation I appreciate the opportunity to testify as to the feasibility and future of the electric vehicle.

For the past six years, the Die Mesh Corporation has had several electric passenger vehicles on the road continuously. We have logged a total of approximately 40,000 miles under urban short-range driving conditions. All of our electric vehicles have been converted from existing internal combustion vehicles, weighing approximately 2,600 pounds, using lead cell batteries and employing regular 110 volt household current with an on-board charger. Therefore, the same safety features that existed before our conversions also exist thereafter. Further, we have employed our own patented electro-drive system in these vehicles, consisting of multiple motors and separate "battery packs" arranged to yield the maximum use of the electrical fuel. I personally drive one of our electric vehicles to and from work each morning. Thereafter during the day it is driven by certain employees of our company to run errands in and about the Town of Pelham. This not only gives us continuous feed-back as to how the vehicle performs under all normal driving conditions, but also is a source of education concerning the use of electric vehicles for our local residents.

Through our continued use of electric vehicles, we have now obtained sufficient data concerning the feasibility of using electricity in a vehicle and also maintaining the safety features of the present internal combustion vehicle. Consequently, we have had preliminary designs for our electric passenger vehicles prepared. These electric vehicles of our own design will embody all of the safety features of the conventional internal combustion vehicle. However, it must be realized that it is absolutely essential that the electric vehicle have its own design and not be a mere conversion. This is due to the fact that the electric fuel is different and therefore requires a different location and a different method of feeding the fuel to the electric motors, controls and on-board charger. It would be just as impossible and impractical to convert an electric vehicle into an internal combustion vehicle.

Concerning the lead cell batteries that are presently being sold for use in electric vehicles, these batteries require no further technological advancements in order to satisfy the requirements of this bill. We have concluded that the battery manufacturers have been unjustly bearing the blame and responsibility for the electric vehicle's lack of advancement. They are neither "the hero" nor "the villain" of electric vehicle progress. In our experience, we have found that a few simple improvements in the current physical make-up of the lead cell battery will make it even more reliable and adaptable for an electric vehicle. As an example, the following items of a lead cell battery could be greatly improved: The terminals of the battery that are in essence the link between the fuel supply and the motor, the plate grids inside the battery, additional fittings on the tops of the batteries to provide for automatic refilling, and, finally, each battery should be given a more thorough inspection so that a realistic guarantee can be given by the manufacturer. An analogy that can be made concerning the improvement of batteries in relation to the electric vehicle can be drawn by observing the advancement of the internal combustion engine from its beginning. Advancement in internal combustion engines came by improving the motor and the manner in which it used the fuel, and not by improving the fuel.

The potential that can be expected in the development of electric vehicles will depend upon the desire and the effort applied, along with the necessary capital to do the job. If one were to seek criteria for measuring the potential for success in new technologies, one would have to begin by examining historical data. This examination would reveal that any thing man can imagine in his mind can be accomplished, given sufficient time and resources. I can recall sitting in my living room watching the miracle of television and listening to several professors describing in a very factual way the depth of the dust on the moon and how an astronaut would sink into the moon dust and the almost impossible odds against landing a man on the moon. This feat is now past history. Perhaps the "doomsday professors" should visit the Smithsonian Institute here in Washington and observe the original internal combustion engines and then visit the Museum of Natural History and examine the ox-cart. These visits would prove emphatically

that the odds are always in favor of progress and new technology. However, the electric vehicle "as is" happens to have the good fortune of being able to meet the limited driving requirements of the vast majority of people in this country today, since more than half of the total automobile miles driven each day across this nation consist of trips of five miles or less. There is no question in my mind that further advancements in electric vehicles will come as they have in other technologies throughout history.

ERDA has at the moment many projects underway, in an attempt to find a better means of producing electricity. It is obvious by the amount of money that the entire world is spending on the same type of projects that the fuel of tomorrow will be electricity, whether it be produced by wind, atomic energy, solar energy or a variety of other means, both natural and man-made. Since this is the case, ERDA, to remain consistent, should give incentive and encourage the electric vehicle industry instead of resisting it. It is only a matter of time before the remaining undeveloped areas of the world demand large amounts of the dwindling fossil fuel supply, thereby totally exhausting it. The time for electric vehicles is now! We feel that the source of ERDA's resistance to this bill is the fact that they have a limited budget to attempt to accomplish a variety of electric vehicle programs. Consequently, there has been a dilution of both efforts and results, creating a negative impression in ERDA's mind about electric vehicles. The implementation of the program as embodied in this Bill will at last provide sufficient capital, which this industry has always lacked, to fund an electric vehicle program that will produce results. Only after this Bill is implemented will ERDA be in a position to compile sufficient data to properly evaluate the electric vehicle and how it conforms to the requirements of this Bill.

The biggest advantage of the electric vehicle is that if implemented on a mass scale, this country will have turned the corner in its war against pollution, which is now on the verge of being lost. In 1966, the Commerce Department found that the internal combustion vehicle was responsible for 60 percent of all man-made, gaseous air pollutants, plus 86,000,000 tons of particulate emissions per year. Pollutants, once produced from the internal combustion engine exhaust, contaminate everything in the general vicinity, such as air, water, soil, livestock and crops. How much saturation of these lethal substances can a human body take? We get up in the morning with headaches, we drink polluted water and breathe in gobs of slow death and discomfort. According to the Environmental Protection Agency, more than half of the total automobile miles driven today consist of trips of five miles or less. For such short trips, the internal combustion engine operates least efficiently and spews out the most pollutants, due to the warming up, idling, stopping and starting, which are indigenous to city driving. With all our affluence, we are no better off than the undeveloped countries of this world. They are dying from lack of progress and we are dying from to much of the wrong kind of progress. The money that has been and will be spent on anti-pollution devices, both in research and development and manufacture, would probably pay for this Bill five times over.

Our company during the past six years has spent over a quarter of a million dollars of its own funds to prove the feasibility of electric vehicles. During that time, we constantly sought the necessary capital from banks, private individuals, the government and Wall Street; all to no avail. With respect to Wall Street, we feel that it is not performing its true function of acting in the interest of the public, itself, and companies seeking capital. Our experience has disclosed that the public is only permitted information about companies of the broker's own choosing which will yield to that broker the fastest profit, without regard to the true value and potential of the company. As for the banks, they refused to get involved in this young industry by lending sufficient capital to companies such as ours, so that we may go into production, without a full Government guarantee backing up that loan. Without Government intervention at this point, the electric vehicle industry will be, for all intents and purposes, dead. The handful of technically qualified small companies that have been "going it alone" over the past years can no longer either make progress or even survive without sufficient amounts of new capital. In our own case, the lack of capital has prevented us from going into full-scale manufacture and sale of on-the-road electric passenger vehicles of our own design. In the past three years, since we entered into various national and international automobile shows, we have been inundated with both written and oral requests for information regarding the purchase of the Die Mesh electric vehicle. However, without the proper funding, full-scale production is not possible.

The ultimate goal of this Bill should be to place technically qualified small companies, such as Die Mesh Corporation, that have had on-the-road experience with electric vehicles over the past years, in full production. Consequently, when the project under this Bill is completed, these companies will be fully capable of continuing the mass production of electric vehicles to meet the consumer demand, which should be substantial by the time this program is completed. Fossil fuels are rapidly becoming "past history", as did the horse-and-buggy upon the dawning of the gas engine. Electricity, and not fossil fuel, is the energy of the future; whether it be solar energy, atomic energy, hydro-electric energy, or any of the other more sophisticated forms of producing electrical energy that our Government is presently working on. To date, all of the tools that man has developed and is using in his history require electrical energy as their prime mover. Therefore, electricity should now be considered our main fuel, which is capable of easy transport to every person in this country by a simple wire.

The electric motor as presently made is suitable to drive an electric vehicle. However, it was never actually designed for the purpose of powering an electric vehicle. With this realization in mind, the Die Mesh Corporation did six years ago begin research into finding the best use of an electric motor in an electric vehicle. From this evolved our patented "Multi-Motor Electro-Drive System". Through this research, we also designed and patented a "Variable Speed Drive" to replace the existing transmission which is presently used in the internal combustion vehicles. Thereafter, we designed and patented a "Variable Speed Electric Motor" as an advancement of our "Multi-Motor Electro-Drive System".

Due to all of our research and development experience with electric passenger vehicles and motors, we are proud at this time to announce our latest invention: "The Modularized Electric Motor." This innovation is a complete departure from the prior art in electric motors. This motor has nine advantages over existing motors:

1. The first and foremost advantage of this new motor is that it is expected to draw only twenty-five percent of the current used by the present-day electric motor.
2. It consists of fifty percent less parts than the motors in use today.
3. It removes twenty substantial problems which beset the present-day motors.
4. It is thirty-three and one-third percent lighter.
5. The coils are water-cooled so that it cannot overheat. The water that cools the coils can be used for heating the cabin of the vehicle.
6. The current draw for this new motor always remains constant, and does not fluctuate with the load.
7. It can be manufactured by the average production lineman, substantially reducing the cost.
8. It can be repaired by the average automobile mechanic by using the spare parts, modularized concept.
9. Each and every part of this new motor is a separate component, so that it can be easily taken apart and replaced.

In summary, the successful operation of this inventive motor is due, in part, to the fact that the forces that are capable of being generated between a magnetic field and magnetic material are of a considerable extent, as evidenced by the ability of an electromagnet to lift tremendous weights with a minimum amount of electric power. This theoretical performance, however, is not properly utilized in a conventional motor because of the movement of a conventional armature in a passing relation to the field. On the other hand, in our new motor, the typical magnetic segment is drawn directly into the magnetic field of the coil. I would also like to point out at this time that the same advantages that apply to this new invention of ours as a motor also apply to it as a generator.

To all of the overly critical voices that have been quick to judge us, I can only say that it is unfair for them to judge this young industry when it is in its infancy stage, without giving it the same chance that was given the internal combustion vehicle. You cannot use the same standards for an electric vehicle that are now applied to the internal combustion engine, which, I might add, began with a crank for a starter, candles for headlights, a tiller for a steering wheel, and a top speed of twenty miles per hour.

All of the advancements we have made have only come because we have been involved with actually making electric vehicles. This demonstrates that advance-

ments and progress, which may seem hopeless in the beginning of a project, become realities if one is willing to work hard for them. With the aid of this Bill, we feel that this is only the beginning.

Mr. Chairman, I would like to compliment you and your colleagues for bringing this Bill forward and for allowing us to participate in these hearings. If you give us the opportunity to make this project a success, I personally promise that we will not let you down.

Thank you.

Disclosure Document—Improved Motor for Electric Vehicle, Domenic Borello, Inventor

This Disclosure Document relates to an improved electric motor, which advantageously can be powered by batteries and, as such, used in powering an automobile or other such vehicle. In a related invention, set forth in U.S. Patent 3,566,714 entitled "Battery-Powered Motor Arrangement", I disclose a unique way of powering a vehicle using a number of electric motors which cooperate with each other to provide the power requirements for the vehicle. In the within Disclosure Document, the same or an equivalent advantageous drive for a vehicle is achieved with a single motor which has vastly improved and advanced drive and powering capabilities. That is, one motor does the work of several motors. Underlying the invention is the recognition that even though a single motor is used, the same can be made to operate much more efficiently than a conventional type when it is acted upon directly by its cooperating magnetic field, rather than urged through its rotation in the conventional manner as is now the practice.

In the enclosed sketch, in Figs. 2 and 3, there is illustrated in simplified form an improved motor demonstrating objects and advantages of the present invention. To better understand what is involved, however, it is helpful to first refer to Fig. 1. In this figure a conventional electric motor is shown which has the usual stator field winding 10 and a rotating armature 12. Underlying the within invention is the belief that there are enormous losses and inefficiencies because of the movement of armature 12 past, rather than through the field 10. This relative movement is illustrated by reference numeral 14.

As an improvement on the above, it is therefore proposed to use a ring-like armature 16 consisting of interconnected non-magnetic and magnetic segments 18, 20. (Only portions of the segments 18, 20 are illustrated in Fig. 2, it being understood that the interconnection of these segments continues along the reference line 22 and thus completes the circular shape of the armature 16.) As illustrated in Fig. 2, the ring armature 16 actually passes through the field coil 24.

Reference should now be made to Fig. 3. Since the ring armature 16 passes through one or more of the field coils 24 it must be supported at locations in between the coils. Thus, use is made of a central support 26 and bearing 28 at strategic locations between member 26 and the ring 16. Reference numeral 30 illustrates the typical manner in which the rotating armature 16 will be utilized to power a contacting member in rotation thus enabling rotative power to be derived from the operation of the armature 16.

In summary, the successful operation of the inventive motor hereof is due in part to the fact that the forces that are capable of being generated between a magnetic field and magnetic material are of a considerable extent, as evidenced by the ability of an electromagnet to lift tremendous weights with a minimum amount of electrical power. This theoretical performance, however, is not properly utilized in a conventional motor because of the movement of a conventional armature 12 in a passing relation to the field 10. On the other hand, in the proposed motor, the typical magnetic segment 18 is drawn directly into the magnetic field of the coil 24. Although not shown, when this occurs, appropriate electrical contacts will be actuated so that the field 24 is demagnetized and therefore the segment 18 is permitted to travel through the field. Field 24 is again magnetized as another magnetic segment approaches it and is therefore effective in pulling the same through its central opening at which time coil 24 is again demagnetized and the cycle is repeated.

A latitude of modification, change and substitution is intended in the foregoing disclosure and in some instances some features of the invention will be employed without a corresponding use of other features.

Re: Improved Electric Motor

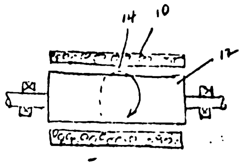

Fig. 1 Prior Art

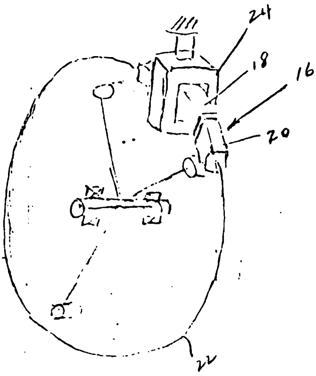

Fig 2

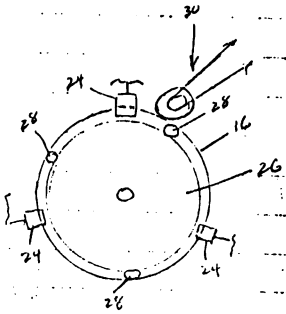

Fig. 3

DIE MESH CORP. POST-HEARING TESTIMONY CONCERNING THE "ELECTRIC VEHICLE RESEARCH, DEVELOPMENT AND DEMONSTRATION ACT OF 1975" (S. 1632 AND H.R. 8800)

Point I: Guaranteed loans

S. 1632 should contain a provision for a guaranteed loan program, so that the technically qualified companies that have been involved with the manufacture of electric vehicles can immediately commence preparing their operations to meet the aims of this Bill, while the Administrator is formulating basic criteria. The guaranteed loan provisions should be patterned after Section 11 of H.R. 8800, entitled "Loan Guarantees". The loan provisions as set forth in the House Bill are satisfactory, with the exception of Subdivision (c), which guarantees only 90 percent of the loan made by a participating bank. This limitation should be eliminated from the Senate Bill. If the loan guarantee provision of this Bill is to mean anything at all, the Federal guarantee should be 100 percent; or else it is virtually certain that there will be very few banks that will participate in this program. No bank will risk 10 percent, 5 percent or even 1 percent on a relatively new venture such as the electric vehicle project which is set forth in this Bill. From our personal experience in approaching banks to become involved in the production of electric vehicles, we were issued a swift turn-down. Banks will not finance a new venture, and if they are exposed to even a 10 percent risk, they will definitely not participate in this program. Therefore, the provision for a 90 percent guarantee is meaningless. However, if the loan is guaranteed 100 percent we are sure that we, or any other technically qualified company, will have no problem obtaining an immediate loan so that we may begin preparing our company to meet the aims of this Bill, pending the implementation by ERDA of the financial arrangements between the various companies that will be involved. Further, any loans that individual, technically qualified companies are able to obtain on their own should be supplemented initially with advance monies under this bill, so that all the necessary initial preparation that the companies will have to undergo will not be delayed by lack of funds.

Point II.—The hybrid

We suggest that you consider what a hybrid consists of before it is made a part of this electric vehicle bill:

1. A complete electrical system combined with a complete gas engine system, including gasoline fuel.
2. It must perform equally to other types of electric vehicles, in spite of the fact that it is carrying the gas engine system plus gas.
3. It must perform equally to some other similar gas engine vehicles, in spite of the fact that it is carrying a complete electric vehicle system, including batteries.
4. It must include all of the safety factors for high speed vehicles.
5. It must be heavier and better-supported in its chassis design in order to carry the two system simultaneously.
6. It will require both electrical and mechanical maintenance stations.
7. The "hybrid" may result in consuming gasoline and making pollution equal to a compact car gasoline engine, because of all the above factors; which is clearly in contradiction of the goals and aims of this Bill.

Point III.—ERDA, the battery and the motor

ERDA, in its testimony on October 10, 1975 before the Subcommittee on Science, Technology and Commerce, did indicate that it felt the total amount of monies outlaid by Congress for this Bill should approximate $240,000,000. Of this, ERDA pointed out that it would earmark approximately $105,000,000 for battery technology, approximately $75,000,000 to electric vehicle manufacturing, and the balance to the demonstration program. This is totally not in keeping with the aims of this Bill, which aims are the making and demonstrating of electric vehicles. To earmark such an exorbitant percentage of the funds that will result from this Bill for battery technology will, in essence, be changing the name of this Bill to "The Storage Battery Development Bill". We are sure that this is not the goal of both Houses of the legislature in bringing this Bill forward. To put such a major emphasis on battery technology would severely hamper and dilute the success that can result from the technically qualified companies' manu-

facture and placing of electric vehicles on the road. Therefore, some form of safeguard should be written into this Bill to prevent the Administrative Agency from earmarking an inappropriate amount of money to battery technology.

This Bill should definitely not single out any one component as the "hero" of electric vehicle advancement. Rather, this Bill should concern itself with all areas where technological advancements can be made, such as, first and foremost, the electric motor, body weight, batteries, controls, charging units, standard charging stations, repair stations, replacement characteristics and standardization of parts common to all electric vehicles. The battery should receive no special attention at this time; for if it is made the key to success, it will conflict with the established aims of this Bill. Therefore, the battery should take its place as an acceptable component that may, through this grant, improve or produce a new technology.

Success in this project will first come from basic improvements, and then through new ideas and inventions. As a matter of fact, Die Mesh Corporation has already invented "The Modularized Electric Motor", as was pointed out at the hearing on October 10, 1975. The advantages of this new motor, as well as an explanation thereof, were contained within Die Mesh Corporation's testimony on the aforesaid date, and a copy of the disclosure document that it filed with the United States Patent Office, explaining its new concept in electric motors, was also submitted. Suffice to say at this time that the first and foremost advantage of this new motor is that it will draw only 25 percent of the current used by the present-day electric motor, as indicated by all of our preliminary tests. This should revolutionize not only the electric vehicle industry, but also the electric motor industry.

From the testimony that was presented by the battery developers at the hearing on October 10, 1975, it was indicated that it would take approximately ten years to develop what those developers felt would be "the best" battery, to wit: The Lithium-Water-Air Battery. Those developers estimated that the cost would be in the area of $15,000,000. However, there is no guarantee that after the ten years this battery will live up to its expectations as enumerated on October 10, 1975. The terms of this Bill call for electric vehicles to be placed on the road as soon as possible, and not to wait for the cure-all battery which may come in ten years. As was pointed out in Die Mesh Corporation's testimony on October 10, 1975, the lead cell batteries, as they are presently being sold for use in electric vehicles, require no further technological advancements in order to satisfy the requirements of this Bill.

It must, therefore, be recognized that batteries alone are not the sole answer to the advancement of the electric vehicle and that there are other technologies that can and will greatly contribute, if given the opportunity.

Senator STEVENSON. The meeting is adjourned.

[Whereupon, at 12:45 p.m. the meeting adjourned.]

ADDITIONAL ARTICLES, LETTERS, AND STATEMENTS

WASHINGTON, D.C., *September 19, 1975.*

Hon. WARREN G. MAGNUSON,
Chairman, Senate Commerce Committee,
Washington, D.C.

DEAR MR. MAGNUSON: Hearings having been scheduled for next October on the Bill S. 1632: "Electric Vehicle Research, Development and Demonstration Act of 1975," I pray you to allow me to present before your Committee my views and related documentation concerning an electric vehicle I devised: Wagon Eureka. I'm Mr. Antonine Lafata Sottile, Ph. Doctor of Electro-Mechanical Engineering. My professional resume is attached to this documentation.

A fair evaluation of the Wagon Eureka merits to be achieved through the wide frame of a complete plan of Transports' Electrification phasing until year 1999 and beyond, when ground traffic could have been cleaned from heat-engine vehicles and air-traffic curbed by ground electro-magnetic suspension-propulsion.

Both Plan three-phase and Wagon Eureka are detailed in the joint Report.

1st phase until year 1983 under sign of TROLLEY. Electrification of Railroads, of Urban Buses, of Highways.

2nd phase until year 1992 under sign of WAGON EUREKA. Expansion of Wagon Eureka Electric Vehicle exploiting gravity for accelerating and decelerating.

3rd phase until year 1999 and beyond under sign of Super-Conducting ELECTRO-MAGNET. Expansion of Electro-Magnetic Suspension-Propulsion.

Year 1992 marked by a law, vetoing the manufacture and marketing of heat-engine vehicles and establishing their total withdrawal from traffic before year 2000.

Year 1999 marked by a law, vetoing transports by air since electro-magnetic suspension-propulsion will allow by that time to fly on the ground at speeds over 800 Km/hr.

1st phase until year 1983 under sign of trolley:

(*a*) Trolley-buses (tired) replacing all operating buses in urban networks.

(*b*) Electrification of Railroads.

(*c*) Electrification of highways by means of overhead power feeder-lines in both right lanes of highways.

Electric vehicles, equipped with flywheels, batteries or whatsoever kind of cells, before exhausting their storage capacity would switch intermittently to the right lane and running at moderate speed could pick-up energy by a trolley.

If already at full capacity and running in a downgrading lane, they could feed the grid. At limits, elsewhere all downgrading lanes could be equipped by overhead power-feeder lines and vehicles running in these lanes could be obliged to recuperate energy and feed the grid.

Electrified Highways will condition electric vehicles, with moderate power storage-capacity for nationwide travels without range limitations, and would *discard "HYBRID" vehicles* which are:

complicated: requiring double installation, that is combustion engine and electric engine, coupling and storage system and requiring for their manufacture double quantity of valuable materials.

heavier and costlier: selling price about 1.5 times the price of a conventional car.

pollutant: what makes them inadaptable for tunnel traffic through urban and interurban tunnels, that has to be implemented (See Report of the National Science Foundation jointly to the American Society of Civil Engineers on the necessity for economical reasons and for other reasons of undergrounding traffic, power transmission lines, and other civil work functions.)

It goes without saying that electrification, requiring a lot of specialized and non-specialized manpower could represent at this time an opportune means to curb unemployment and related problems.

2d phase until year 1992 under sign of Wagon Eureka.

Wagons Eureka, ranging from bus and truck sizes to passenger compact vehicles are:

Suited for existing roads, for future surface-or-tunnel roads (At. La. S Utilities) and for future leanway system of subway, both kinds of roads and tracks, uni-directional consisting of successive alternances of steep downgrades and upgrades to exploit gravity.

Equipped by flywheels, as gyroscopic stabilizers of the wagon-floor-deck permanent levelness (in spite of steep downgrades and upgrades continuous succession) and as accumulators-recuperators of energy.

Complemented in the intermediate phase of development by a trolley for intermittent pick-up of energy from overhead feeder-lines, by solar cells and by every kind of means apt to recuperate and store energy.

Equipped during the advanced phase of development, by coupling devices utilizing the propulsion impressed by a Linear Induction Motor or Synchronous Linear Motor installed on the ground along the terminal steep upgrade of each alternance (say along 10 percent of the total run) and propelling the vehicle until the next downgrade.

In that way the Wagon Eureka, exploiting gravity, for 90 percent of each run and electromagnetic propulsion for the remaining 10 percent could assure the following advantages:

No problems of adhesion: No limitation of grade.

No on-board powerful Motor.

No pick-up of energy from exterior feeder line.

No limitation of speed: the steeper the adopted grade, the higher the acceleration and the speed; only limitation of acceleration imposed by the passengers' comfort: in the range of 1.4 m/sec^2.

Low requirements of installation and operation.

High rate of energy savings.

The wagon Eureka will permit.

(*a*) Expansion of Leanway—New kind of cheap, clean, efficient, unidirectional subway, supplanting gradually all operating surface networks of buses.

(*b*) Expansion of At. La. S Utilities—New kind of urban uninterrupted traffic without stopping lights at crossings.

(*c*) Adoption of At. La. S interchange instead of the costly complicated conventional clover-leaf interchange.

(*d*) Adoption of tunnels underpassing rivers instead of bridges crossing rivers.

(*e*) Adoption of underpasses at the around 250,000 railroads-grade-crossings eliminating their yearly average toll of 1,200 deaths, 3,500 injuries, and invaluable loss of goods and time.

(*f*) Expansion of underground traffic through urban and interurban tunnels.

3d phase until year 1999 and beyond under sign of Super-Conducting Electro-Magnet:

Expansion of Electro-Magnetic Suspension-Propulsion in railroads: Before all in consideration the Northeast Corridor (NEC) Boston-Washington followed by other 9 corridors under study.

Expansion of Electro-Magnetic Suspension-Propulsion in highways.

Requirements of Power for Electro-Magnetic Suspension-Propulsion, Costs of construction and requirements of materials; considerable.

Suspension: The on-board superconducting Electro-Magnet "in the persistent mode of operation" requires a negligible amount of power; order of 20 KW. to operate only the closed cycle Helium-Nitrogen refrigerator.

Propulsion: The power required is widely related to the speed. The Japanese levitated train Tokio-Osaka, scheduled to go into operation in 1985 could require 90 MW for 16 coaches, each coach of 30 metric tons weight. Propulsion assured by a Linear Synchronous Motor with primaries stationary and located on the ground, in order to avoid pickup of energy by vehicles flying 25 cm. over the ground at 550 Km/hr.

Total cost of the line: 7 billion dollars (about 14 million $/Km both ways). The coils laid on the ground, all the way, contribute to increase cost.

Alternate solution of a continuous double-L-shaped aluminum guideway = 220.000 Kg./Km. of line both ways.

CONCLUSION

A net distinction between the functions of suspension and propulsion respectively could expand to the 3rd Phase the concept of the Wagon Eureka, outlined before: with its enormous savings of energy and low requirements of installation and operation.

Propulsion assured by gravity during 90% of each alternance: by the primaries laid on the ground of a Linear Motor for the remaining 10%, in steep upgrade until surfacing again.

Suspension assured by one of the means available not excluding the possibility to exploit the electro-magnetic field generated by criogenic underground cables for transmission of high density electric power.

EXPLANATION

Wagon Eureka levelness.—A spherical bearing lets the body to pivot by gyroscopical effect over underframe (chassis) always parallel to the changing grade.

At.La.S.: Alternance lanes system.—A 1968 project of a new urbanization with uninterrupted traffic.

Leanway: A leaning subway.—A 1974 project.

Innercity leanway.—Single vehicles surfacing to stops near the curb every few blocks replacing and expanding current bus lines.

Intercity leanway.—Plurivehicle trains surfacing to stops few Km. apart.

For both leanways.—Unique interchangeable kind of Wagon Eureka.

NOTE.—Copy of Statement presented to the Senate Commerce Committee, on the Bill S. 1632 "Electric Vehicle Research, Development & Demonstration Act of 1975" (October Hearings). Complemented by the Statement presented to the House Science & Technology Committee on the Bill H.R. 5470 (June Hearings). See pages 728 to 740 of the House Record "Electric Vehicle R. D. & Demo. Act of 1975."

RÉSUMÉ

February 21, 1971 to present in Washington, D.C. area—Researching on Subway and other fields.

1970 in Laredo, Tex.—Divising a new system of mechanical spiral escalator.

1968–1970 in Mexico City U.N.A.M. University.—Researching and lecturing on Laser beam.

1967 in Mexico City Secretary of Public Works.—Devising a new system of urban traffic, without signal controls.

1965–1966 in Santiago, Chile Ministry of Public Works.—Devising a new system of subway.

1958–1965 in Paris, France Ministry of Public Works.—Statistics and planning of public works in the Paris region.

1954–1957 in North Africa Public Works.—Construction of roads in Algeria and Morocco.

7 years in a company synthesizing ammonic by-products in Italy.—Chief of Electrical and Electrolysis Departments, Manager of factories, Vice-director in the Rome general direction.

Personal printed papers

Energy Manifesto: Plan Three-Phase of Transports' Electrification (English) 1975.

Project of Leanway (a leaning subway) (English) 1974.

Project of "Automatic Spiral Lifter" (escalator) (English) 1970.

44 articles published on "Laser Beam" (Spanish) 1970.

Booklet on "Laredo City-planning and Economical Resources" (English) 1970.

Booklet on "The Laser and its Utilization" (Spanish) 1969.

Project of "Urban Traffic without Signal Controls" (Spanish and English) 1968.

Project of "Alternal Leaning Subway" (Spanish and English) 1966–68.

Technical books translated from English and French into Spanish (Spanish) 1967.

Compendium of "Public Works in the Paris Region" (French) 1964.

Booklet on "Electrical Installations in a Nitrogen Factory" (Italian) 1943.

Inventions

New kind of Subway car: Wagon "Eureka", 1974.
New system of automatic spiral lifter, 1970.
Laser beam devices to detect fire, gases, earthquakes, etc., 1969.
New system of urban traffic without signal controls, 1968.
New system of metropolitan subway, 1965.

Foreign languages

French, Spanish, Italian (Excellent) Speak, read, write, understand.
German (Fair) Speak, read, write, understand.

High level knowledge

Mathematics, Physics, Laser, Electrotechnics, Subway, Roads, City-planning, etc.

ANTONINE LAFATA SOTTILE.

STATEMENT OF AMERICAN PUBLIC POWER ASSOCIATION

American Public Power Association, representing 1,400 local public power systems in 48 States, Puerto Rico, Guam, and the Virgin Islands, strongly supports enactment of S. 1632, the Electric Vehicle Research, Development, and Demonstration Act of 1975.

Awareness of the advantages of electric vehicles is growing as the need for energy conservation becomes more apparent. For example, the House of Representatives in September approved by a vote of 308 to 60, H.R. 8800, a measure which is similar to S. 1632.

APPA supports S. 1632 because enactment of the bill will help demonstrate the benefits of electric vehicles, conserve petroleum, and reduce air and noise pollution.

Electric vehicles would permit more efficient use of electric plant capacity since their batteries would usually be recharged at night during electric generating off-peak hours.

About one-fourth of the total energy in the United States is consumed annually by our transportation systems, about one-eighth of which can be attributed to automobiles according to the Energy Research and Development Administration (ERDA). There are approximately 100 million vehicles powered by petroleum in the country. Currently, the U.S. cannot fulfill 35% of its oil needs from domestic sources and must import about 6 million barrels a day of foreign oil. It is apparent that an alternative to gasoline-powered vehicles is needed which could cut some of the nation's dependence on foreign oil.

The electric car is noiseless and does not pollute the environment. About one-half of the total automobile miles driven today consists of trips of 5 miles or less. Envisioned as a second care, the electric vehicle would be used around town for these short trips and errands. Approximately 80% of urban traffic is stop and go, and this is when conventional internal combustion engines release the most harmful emmissions. The electric vehicle has no pollutants to release and does not use energy when it is standing still.

It is true that pollutants will be released from the electric generating plants used to charge electric vehicles if coal or oil is used as a fuel, but these emissions from a stationary facility are easier to control than those from moving vehicles. Moreover, most generating plants are not in the heart of an urban area. There of course will be no significant air pollution if hydro or nuclear power facilities are used to generate electricity for the cars.

APPA supports the basic aim of S. 1632, which is to develop a vehicle that is commercially feasible to meet the transportation needs of the country and which will not depend on petroleum for power. The House-passed bill, H.R. 8800, calls for a five year research, development, and demonstration program costing $160 million. ERDA would contract with private industry to produce and develop within 15 months 2,500 electric vehicles using conventional automobile chassis. ERDA would contract for another 5,000 vehicles to be leased throughout the country within three and a half years as part of the research information gathering and demonstration project. Leasing to the public would provide valuable information on the operation of the car, and the reaction of consumers. Vehicles in the second phase would use frames especially designed to maximize electric power. Production of up to 7,500 vehicles is expected to stimulate and promote competitive development.

S. 1632 calls for a three year program for research and development of 10,000 or more electric vehicles.

APPA is especially pleased with the section of S. 1632 that provides for research and development of batteries for electric vehicles. Nine years ago, APPA presented testimony before the Senate Subcommittee on Air and Water Pollution, urging development of a lighter, longer-lasting and less expensive battery for electric vehicles than was then in existence. Since then, battery development has progressed so that the average range of an electric vehicle is 60 miles with a speed up to 50 miles an hour.

However, according to ERDA testimony before the House Subcommittee on Energy Research, Development and Demonstration in June, lack of sufficient progress in improvement of the lead-acid battery is the one obstacle to achieving the goals envisioned by H.R. 8800 and S. 1632. Dr. James S. Kane, Deputy Assistant Administrator for Conservation of ERDA said, "The single most important drawback of the only currently available battery (the lead-acid battery) is its high life-cycle costs due to its relatively short life. This cost factor is the main deterrent to widespread use of electric vehicles today."

APPA suggests that to insure full implementation of the sections of S. 1632 calling for testing and evaluation of available batteries, Congress should urge ERDA to include batteries from other countries. For example, Toyota of Japan has recently announced its development of a five-passenger electric car prototype that has a 125 mile range at a speed of 58 miles an hour. There are about a million electric vehicles in use throughout the world. Although 90% of these are off-road vehicles, there would certainly be merit in examining their components.

Continuing its interest and involvement in the development of electric vehicles, APPA has participated with a group of electric utilities in the purchase of over 100 Battronic trucks to be used for light general utility delivery. In addition, the Electric Vehicle Committee of APPA has an on-going study of electric vehicles and in continuing to review developments.

APPA supports S. 1632 as a means of stimulating the country's technological potential to develop electric vehicles.

JET INDUSTRIES LTD.,
Seattle, Wash., September 3, 1975.

Mr. ALAN HOFFMAN,
Senate Commerce Committee, Automobiles & Electric Vehicles, Old Immigration Building, Washington, D.C.

DEAR ALAN, I have delayed writing to you because of the difficulty of defining some wording to be included in the Senate Electric Vehicle Bill which would be meaningful.

If you will notice that the excerpts from the House Bill 5470–8800 leave the present problem of commencing the conversion of imported I/C vehicles to electric battery power, which cannot be resolved for an indefinite date in the future and even then, it might take some specific legislation to earmark the specifics needed for this purpose.

Hoping that we're not too late to have these recommendations included in the Senate version of the bill, I am

Sincerely yours,

A. FORBES CRAWFORD, *President.*

Enclosure.

RECOMMENDATION

We recommend that the following be inserted in SEC. 9 in front of (d): "Immediately upon the enactment of this ACT, all Electric Vehicles may be licensed for use on public highways under individual State vehicle laws prevailing for vehicles prior to the 1966 NHTSA safety Standards. This provision shall remain in effect for a period of ten years", and (d) "The Secretary of Transportation shall conduct a study on the current and future applicability of safety standards and regulations to electric and hybrid vehicles and shall report the results of such study to the Administrator within two hundred forty days after

the date of the enactment of this ACT, and hereafter the ERDA Administrator may recommend such revisions of Safety Standards for Electric Vehicles as may be necessary." (This would relieve ERDA of part of their responsibilities by shifting licensing to individual state ERDA and DOT offices.

In addition, any complete automotive vehicle imported for conversion to EV and components imported for use in manufacturing EV's shall not require NHTSA approval by customs.

EFFECTIVENESS ELECTRIC VEHICLE BILL

In order to have its own autonomous Effectiveness to promote Electric Vehicles, ERDA must initially have incorporated in the House Bills H.R. 5470–8800,a distinct authority of its own which is specific as to safety requirements, import and duty provisions of automotive and other vehicles for conversion to EV and automotive and other components used for the production of electric vehicles. Attached is a separate memorandum outlining some specific contradictions that have been experienced already by Jet Industries, Ltd. in trying to import automotive vehicles to convert to electric battery power and automotive components to use in its own production of electric vehicles.

In view of these it seems important to examine some of the excerpts from H.R. 5470 and 8800:

Under "Policy & Goals" SEC. 3 (b)—(2) reads "to implement this policy by removing institutional barriers to such substitution where otherwise practicable;

Under "Management" SEC. 5 (b) reads "The overall management of the project shall be the responsibility of the Administrator, but he may enter into such arrangements and agreements with the National Aeronautics and Space Administration, the Secretary of Transportation, the National Science Foundation, the Environmental Protection Agency, the Secretary of Housing and Urban Development, and other Federal officers and agencies as he may deem necessary or appropriate for the conduct by them of parts or aspects of the project which are within their particular competence."

Under "Demonstration" SEC. 7 (b) (1) reads "Within one year after the date of the enactment of this ACT, the Administrator shall develop or arrange for the initial performance standards and Criteria which are suitable for the needs of urban private passenger vehicles and urban commercial vehicles (and which shall be applicable to the vehicles produced under subsection (a)(2). The standard and criteria so developed shall not be designed simply to reflect the characteristics of current internal combustion engine automobiles and trucks, but shall also take into account the factors of energy conservation, urban traffic characteristics, patterns of use for "second" vehicles, consumer preferences, maintenance needs, battery recharging characteristics, materials demand and recyclability, vehicle safety and insurability, and other relevant considerations, as such factors and considerations particularly apply to or affect vehicles with electric or hybrid propulsion systems. Such standards and criteria are to be developed and determined utilizing the best current state-of-the-art and utilizing the state-of-the-art that would be projected to result from the research and development program described in section 6. These performance standards and criteria shall be revised periodically as the state-of-the-art improves. In developing such standards and criteria, the Administrator shall consult with appropriate authorities concerning design needs for electric and hybrid vehicles compatible with long range urban planning, traffic management, and vehicle safety."

Under "Incentives and Assessments" SEC. 9(d) reads "The Secretary of Transportation shall conduct a study on the current and future applicability of safety standards and regulations to electric and hybrid vehicles and shall report the results of such study to the Administrator within two hundred forty days after the date of the enactment of this Act."

Under "Reports to Congress" SEC. 12 (2) reads "and a statement of the extent to which imported automobile chassis or components are being used, or are needed, for the production of vehicles under section (a), and the extent to which restrictions imposed by law or regulation upon the importation or use of such chassis or components are interfering with the achievement of the purpose of this ACT, each such report shall also include any recommendations which the Administrator may deem appropriate for legislation or related action which might further the purposes of this Act."

SUMMARY

All of the foregoing applies to the future. This means that after any House and Senate Bills are passed and compromised, staff organization, their responsibilities and accomplishments will take considerable time.

In order for ERDA to be immediately effective the following recommendation is proposed.

RECOMMENDATION

We recommend that the following be inserted in SEC. 9 in front of (d): "Immediately upon the enactment of this Act, all Electric Vehicles may be licensed for use on public highways under the individual State vehicle laws prevailing for vehicles prior to the 1966 NHTSA Safety Standards. This provision shall remain in effect for a period of ten years", and (d) "The Secretary of Transportation shall conduct a study on the current and future applicability of safety standards and regulations to electric and hybrid vehicles and shall report the results of such study to the Administrator within two hundred forty days after the date of the enactment of this Act, and thereafter ERDA Administrator may recommend such revisions of Safety Standards for Electric Vehicles as may be necessary." (This would relieve ERDA of part of their responsibilities by shifting licensing to individual state ERDA and DOT offices.

In addition, any complete automotive vehicle imported for conversion to EV and components imported for use in manufacturing EV's shall not require NHTSA approval by customs.

ELECTRIC VEHICLES VERSUS NHTSA SAFETY STANDARDS

It must be recognized that electric battery powered and hybrid vehicles must be treated in a very distinct manner separate from I/C powered vehicles. The current safety standards required by NHTSA should not apply to electric vehicles for the following reasons:

1. It is recognized that electric vehicle chassis must be lightweight but strong in order to develop their maximum commercial and passenger feasibility. Modern automotive and aircraft techiques can be combined to reach this stage of development. An example of the contrast is the fact that the American Motors converted Jeep and the Otis Elevator electric vehicle both have leaf springs in the front and rear which are a type of suspension used since the beginning of automobile manufacture in the 1890's. Whereas Jet Industries' vehicle conversion has a type of modern suspension that the manufacturer has spent millions of dollars developing. This suspension is one that can be adjusted to loads and has tremendous possibilities in the electric vehicle field.

2. Electric vehicles initially should be designed primarily for urban use with maximum speeds not to exceed 45 m.p.h. (or 50 at the most), therefore not having the top speed of I/C vehicles. In addition, electric vehicles do not have the acceleration of I/C vehicles for "drag-type" performance which is responsible for a large percentage of I/C accidents. The acceleration ability of the electric vehicle to keep up only with urban traffic develops a cautious type of driver and it is predictable that accident rates will be far below those of I/C powered vehicles.

3. The predicted number of electric vehicles which might be on the highways in the next five years are minimal compared to the millions of I/C powered pre-1966 vehicles still on the road. These I/C vehicles will continue in large numbers because many owners are finding that it is cheaper to maintain these vehicles than buy new ones.

4. The electric vehicles are in all circumstances very much safer than the hundreds of thousands or maybe several million motorcycles licensed for public highways. This is also true of bicycles and scooters.

The forgoing are the reasons why electric battery powered vehicles should have to comply only with the pre-1966 NHTSA safety standards.

NHTSA CONTRADICTIONS

In the case of Jet Industries trying to begin converting to electric battery power I/C powered vans imported from Japan, the following contradictions have developed:

1. When trying to get permission to import several hundred vans to convert to electric battery power and licensed for use on public highways:

A. To develop the technological problems existing in all 50 states: This means the terrain of the country, distances to be traveled, climatic conditions (heat, cold, humidity, etc.).

B. That this was the only way that we could economically develop these vehicles. We were rejected by NHTSA by their statement that we could use two vehicles already in the United States and Canada for these testing purposes.

2. On our suggestion that we be allowed to import these for conversion to electric battery powered use for In-Plant (off-highway) use, NHTSA said that this could not be done because the vehicles were originally designed for highway use. And one staff member of NHTSA said they couldn't allow it because these vehicles, after being for In-Plant use might be registered by the owners for public highway use. This was in spite of the fact that we informed them that the vehicles would be sold primarily to fleet users from whom we could get an undertaking not to license them for public highway use.

3. When we asked if we could import the vehicles in the United States without the internal combustion engine and transmission we were told that this could not be done either. They advised us that we could import all the different components as automobile parts and assemble them. This, of course, would require the tooling and expense of setting up a production line which would be very uneconomical at this stage of anticipated volume of electric vehicles.

4. When we asked if we could import the vehicles without the engine and transmissions we were told by the NHTSA that we could not because they were complete vehicles originally designed for I/C public road use. When we talked to the attorney in the Commerce Department who was responsible for writing the original NHTSA bill, he said that this was not a correct statement by the NHTSA.

5. It is possible for a company like us to apply for an exemption from NHTSA standards for as long as a three year period. The application form must state the specific items which are requested in the exemption application and for us to state specifically when these could be corrected. The problem here is that the foreign manufacturer of this lightweight vehicle is not going to engineer and tool up to make changes in their production vehicle to satisfy NHTSA standards because their vehicles as internal combustion vehicles are accepted for public road licensing in their own country in their present condition. They will not commit to any specific time or cost of making such changes. Nor would it be possible for us to make the changes ourselves because of the exhorbitant cost of what we would call—"Job-Shop" type of operation.

The request for exemption from NHTSA standards requires some sort of public notice during which time an I/C competitor of electric vehicles can come in and object to our request for the exemptions. Also, any type of business that competitive to the electric vehicle business could do the same thing. During this ninety day period, an electric vehicle manufacturer has to sit on his hands and cannot make commitments for the purchase of components for which there is a ninety day or more lead time and cannot get commitments for financing or other types of business requirements such as administrative personnel, work force, etc.

It is very obvious that electric vehicle safety standards must come directly under the administrator of ERDA so that there can be no misunderstandings and conflicts in this connection.

IMPORTATION I/C VEHICLES FOR CONVERSION TO ELECTRIC BATTERY POWER

The logistics and costs of importing I/C vehicles for conversion to electric battery power are outlined as follows:

1. For the foreign manufacturer of I/C vehicles to program their computers to eliminate the production facility and for these to not arrive at the assembly line is not justified in view of the limited number of vehicles which may be demanded in the U.S. for conversion to electric battery power. In addition to engineer and program a substitute axle and suspension for the vehicles is also a costly matter.

2. The actual labor involved in this type of substitution becomes a problem from the standpoint of training personnel.

3. If such a substitution were made, it would be necessary to push the vehicle from the end of the assembly line to a storage yard and then push the vehicles onto an automobile transporter to be taken to a dock storage area. Following would be the necessity of pushing it off the transporter in and around the dock storage area, back to ship loading area and around the ship itself.

4. The same procedures as number 3 would be reversed upon the arrival of the vehicle in the United States.

Both the foreign manufacturer of the I/C vehicle and U.S. converter of this vehicle to electric battery power concluded that the logistics and costs of scrapping the I/C engine and transmission were less of a problem and less cost than trying to work out the delivery of the vehicle without the engine and transmission.

Under present NHTSA regulations such I/C vehicles cannot be imported into the United States for production purposes because they do not meet NHTSA safety standards. A separate memorandum has been prepared entitled Electric Vehicles vs. NHTSA Safety Standards.

The jaws that threaten the nation's well-being are not those on the giant fish that looms up in front of moviegoers, but those on the yawning capital gap that faces the U.S. this year and as far ahead as anyone can see. or the failure of the supply of capital to keep up with demand could eat the nation's standard of living alive.

The amount of capital that the U.S. needs if it is to move back to its historic real growth rate of 4% a year and stay there is enormous by any measure. Between 1955 and 1964, the U.S. economy consumed $760-billion in capital in turning out all the cars and TV sets, in building all the houses and factories and shopping centers that a growing population wanted. Between 1965 and 1974, the nation's consumption of capital doubled to $1.6-trillion. By the best estimates available, the U.S. will need the incredible sum of $4.5-trillion in new capital funds in the next 10 years: capital that, for the most part, will have to come from the savings of the American people and the profits of American business.

Looked at in a slightly different way, the nation's total supply of capital will have to rise at a compound annual rate of 8.7% during the next decade, compared with a compound annual rate of 6.7% in the past decade.

UNPLEASANT CONSEQUENCES

The obstacles to raising that kind of money in the economic environment that is likely to prevail in the next decade, and distributing it to where it will be needed, are formidable, perhaps insurmountable. But the social and financial consequences of not generating sufficient savings to provide money on that scale are not pleasant to contemplate. A capital shortage of the magnitude that seems possible would make the U.S. economy a tough place for anyone—individuals and giant corporations alike—to making a living. This is what a capital crisis would mean:

The financial markets would be chronically unable to provide the necessary flows of funds to finance the economy's expenditures at rates of interest that anyone could afford. Indeed, under the lash of a federal budget deficit of more than $100-billion in two years, this symptom of a capital shortage is already present in the U.S. financial markets even though the demand for funds is low because of recession. Short-term interest rates have turned higher again, and long-term rates are already near or at historic peaks even though the economy is only in the early stages of recovery. or a disturbingly large number of would-be borrowers, from New York City to some of the nation's largest corporations, there is no money to be had today at any price.

The U.S. economy would suffer from both chronic shortages of goods and from continued high inflation because capital expenditures by business would be insufficient to generate enough capacity to meet demand at reasonably stable prices. A low utilization rate virtually guarantees that the U.S. will not become a true shortage economy again until 1980 at the earliest. But there will be areas of shortage before then, and when and if the economy moves back to full employment, the press of growing demand against less rapidly growing supply will become acute. Shortages of such basic stuff as chemicals, paper, and steel were already disturbingly visible during the last period of high employment in 1973 and early 1974. Next time, there could well be shortages of nearly everything.

The business cycle profile would consist of short, feeble recoveries quickly aborted. Constant upward pressure on interest rates, and high inflation, will force the Federal Reserve into a tight money stance early in recoveries, much as seems to be happening right now. This will make prolonged business upswings impossible but prolonged recessions easy.

The corporate structure of the U.S. would begin to resemble Japan's zaibatsu economy as strong companies gobble weak companies at an accelerati ce. The

capital-short economy discriminates against any company that does not have the highest credit rating because lenders of scarce funds can afford to hold out for only the very highest ratings. Already there is a tiny group of companies that can raise new equity capital, a larger group that can raise debt capital, and a very large group that cannot raise any capital at all. There may not be a capital shortage for all, but there almost surely will be a capital crisis for some. More and more of these bottom tier companies will fall by the wayside as the capital shortage becomes more intense.

Social unrest and class conflict would become endemic because income gains will be thin to nonexistent. It is indeed naive to imagine that the capitalist-mixed economy can long survive a capital crisis. A nation that has been convinced that it can grow at a fast clip—that every person has the right to a job, an education, two cars and a house in the suburbs—will have to live instead within the strict limits on the growth of income imposed by a capital shortage. "A central feature of modern economic society," says John Kenneth Galbraith in his new book Money, "is the rejection by subordinate classes of the prescriptive limits on their income and consumption. With this rejection go claims on production that cannot be met; from these claims come inflation."

UTOPIAN ASSUMPTIONS

A severe capital crisis in the years ahead is not foreordained. The only completed, detailed studies of the long-term capital outlook that are worth their salt—the studies by Barry P. Bosworth, James S. Duesenberry, and Andrew S. Carron for the Brookings Institution, and by Roger E. Brinner and Allen L. Sinai for Data Resources, Inc.—conclude that the U.S. will skirt the ragged edge of a severe capial gap rather than fall into it. But these studies are based on what could well turn out to be utopian assumptions, as their authors admit. In the Duesenberry-Bosworth-Carron study, the federal budget comes into balance in 1977 and stays there. In the Sinai-Brinner study, the balance is achieved in 1978.

Yet the conditions that threaten a capital shortage are the very same ones that could easily undo these optimistic assumptions about inflation and spending. The grim reality is that budget deficits promise to be deeper than expected and inflation higher than expected, and the U.S. can escape a capital crisis only if it is luckier or wiser than it has been in the past.

So far, at least, both luck and wisdom seem to be in short supply. On the evidence, the U.S. has chosen not to deal with the real threat of a capital gap but simply to ignore it. Closing that gap at a minimum requires changes in the tax structure that would provide greater incentives for savings and investment and greater disincentives for consumption. It is true that the Ford Administration has recognized the need for such changes and has proposed legislation aimed at improving the tax treatment for savings and investment. But what is mostly involved is a cut in the corporate tax rate—political quicksand in a year of near-9% unemployment.

There are three related reasons for this indifference to the capital shortage issue. The capital gap is difficult to define, difficult to measure, difficult to understand, and therefore difficult to take seriously. Closing the capital gap would require changes that would be painful to many, since they would require people to consume less in the short run so that society may grow faster in the long run. And, finally, the most vocal proponents of the existence of a capital gap—corporate lobbyists, organizations like the New York Stock Exchange and the Securities Industry Assn.—represent those in society that would benefit most directly from measures designed to close it. It does not help that Washington's No. 1 capital gap crusader, Treasury Secretary William E. Simon, has a Wall Street background with the investment banking house of Salomon Bros., a firm that would obviously benefit from pro savings, investment legislation. It certainly does not help that Simon has done far better at selling bonds to Wall Street than legislative proposals to Congress.

Difficulties with the definition of the capital gap exist because there is a sense in which there is *always* a capital gap, a sense in which there is *never* a capital gap, and a sense in which a capital gap can exist at some times but not at others.

BALANCING GOALS AND SUPPLY

A capital gap can always be said to exist because human wants are insatiable. Any company that turns its engineers loose can always make a list of capital projects that it would like to complete that stretches from the earth to the moon.

And so can any unit of government or any individual. Indeed, in its study of the capital gap that came up with an $650-billion capital shortage for the next 10 years, the NYSE came perilously close to this. The exchange's research department, in effect, estimated the capital needs of industries and units of government without analyzing whether the needs are realistic in the framework of the overall economy. As a consequence, the exchange left itself open to ridicule from many economists and from the labor movement (page 109).

The view that a capital shortage never exists is one that deserves to be taken far more seriously. Robert Eisner, a Northwestern University economist, who is a leading proponent of this position, calls the capital gap "a lot of bull." In an economic sense, he says, "it doesn't make sense to talk of a shortage of either physical or financial capital." We live in an economy, he argues, where consumers and investors state their preferences and the market acts as a great clearinghouse. If people do not want to save enough to meet supposed requirements, he says, "that's just tough." If the demand for capital is greater than the supply at existing rates of return, then those rates of return and real interest rates should rise and induce more savings. Eisner is critical of Treasury Secretary Simon. "It galls me that a guy like Simon, who says that he believes strongly in the free enterprise system, really doesn't trust the market," he says.

Yet there is an essential difficulty with this view that a capital gap cannot exist, since the market equates the supply of savings with the demand for investment. And that difficulty is simply that a society that is too profligate in consuming rather than saving will put such a high price on capital and therefore produce so little of it, that it will not grow fast enough to meet some commonly accepted goals.

It is, in fact, a study of the balance between commonly accepted goals and the supply of capital that is available to meet those goals that gives a rigorous economic meaning to the notion of a capital shortage. The question is not will there be a capital shortage, for the answer to that question is both "yes" and "no." Rather, the question is, given certain goals for economic growth and total employment, will the U.S. generate enough capital to meet them.

Sound studies of the capital shortage do not, therefore, concentrate primarily on coming up with boxcar numbers to scare people with, such as the NYSE's $650-billion. Rather, they begin by asking where the economy is now and where Americans would like it to be in, say, 10 years. They then go on to estimate the capital constraints that are likely to be met on the way. In this sense, the capital shortage problem becomes a part of the whole question of economic growth, and once the capital shortage is looked at in this way it begins to take on some real meaning.

ACCUMULATING CAPITAL

Every since the days of Adam Smith, and even before, economists have recognized that a simple—if painful—condition be met: A society must, each year, produce more than it can consume. And if that society is going to grow, it must be able to find a mechanism by which the margin between production and consumption is invested in capital goods that can be used to increase productivity.

(Indeed, as the classical economists up to and including Karl Marx demonstratede with a clarity that eludes modern economists, the entire history of civilization is bound up with capital accumulation. Man ceased to be a hunter and began to develop the arts of civilization only when the then-fertile area between the Tigris and the Euphrates—ancient Mesopotamia—began to produce agricultural surplus that could be used to support a nonagricultural population. Civilization was similarly first brought to a high form in ancient Egypt largely because the incredible fertility of the Nile's flood plain permitted the first really wide margin between production and consumption. The real breakthrough for the Western world came, of course, with the invention of the steam engine, which led to a quantum jump in productivity and permitted the economies of the West to develop at an incredible pace.

The Industrial Revolution required a huge margin between production and consumption, and that margin has stayed high for more than 200 years. The margin between production and consumption, which economists call savings, is in part determined by the stage of economic development a nation is in. As the table on page 92 shows, the margin is widest in Japan, which is still in the relatively early stages of development and lowest in the so-called mature economies like Britain and the U.S.

The U.S. has managed to get by with a low savings-investment rate, and can still do so compared to most countries. But in the past decade, the claims on that

margin between production and consumption have become increasingly vociferous—from business, the public, and government—as both the willingness and the incentive to save has become atenuated.

Over the past 10 years government spending, including transfer payments, have been increasing at an astonishing 9% annual rate, more than double the 4% rate for the private economy. That growth of government speending lies at the heart of the capital market strains that have appeared in the past year. Although not generally recognized, economists view the government as a potential saver, counting government surpluses as well as personal and corporate setasides from production as part of the naton's total supply of savings. On the other hand, government deficits count as a claim against savings. In physical terms a government deficit means that the government is a net consumer—drawing more resources out of the economy than it is putting back in and eating into the margin between production and consumption.

THE MARGIN GETS SMALLER

Happenings in the fiscal markets represent the dollar analogy to the physical shortage of capital. Those who refrain from consumption provide funds to the financial intermediaries—the banks and other lenders—who then have the funds available to support investment. And a thin production-consumption margin leads to a thin supply of capital. The consequences of a thin capital supply are either.

Rising interest rates as a strong demand for capital competes for the available supply. A capital shortage cannot actually be seen, since the price of capital (interest rates) keeps rising until, on any given day, supply and demand are balanced. Longer-run, though, the number of individuals and businesses that want capital, but cannot afford it, keep growing.

Moves by the Federal Reserve to make up for the financial market capital shortage by pumping more money into the ecenomic system. But if the total amount of funds exceeds the amount that is generated by savings (the difference between production and consumption) the result is inflation.

The possible outcomes of a financial market capital shortage are not confined to these two extremes. In an economy that does not save enough, it is possible and even likely that the financial markets will follow a zigzag pattern, alternating between periods of tight money and soaring interest rates, and periods when the Federal Reserve tries to hold rates down by pumping money into the system.

The worthwhile studies of the capital shortage do not proceed in a vacuum. They emerge from simulations of the performance of the U.S. economy and of economic policy during the next decade. They then go on to estimate the capital requirements that result from these simulations. And while the studies disagree on details, there is agreement among them on what the basic contours of the economy will be and what will have to be done if a severe capital shortage is to be avoided.

All studies begin by recognizing that business will be the key capital user during the next decade. According to the Data Resources study, for example, business investment in machinery (technically producers' durable equipment) will have to rise at a compound annual rate of 11.5% during the next 10 years vs. an 8.9% annual rate between 1965 and 1974. To finance that spending, given an expected 5% to 6% inflation rate, companies will have to spend some $1.9-trillion in the next decade against $670-billion in the next decade.

There are a number of reasons why capital spending will have to grow at an accelerated pace. To begin with, the rate of capital spending has been low relative to the rate of growth of ouput in the past decade as the government sector (federal and local) grew faster than the private sector. Also, the pollution and safety laws have increased the capital required for a given level of production. And, finally, there are signs that it is now taking more and more dollars worth of capital to produce one dollar's worth of output.

HEAVIER BORROWING AHEAD

But this is not the only capital spending problem and perhaps not the main one at all. It is clear, says Gary Fromm, who is conducting a capital spending study for the National Bureau of Economic Research, "that inflation will continue to take a substantial bite out of investment potential." On the corporate side, inflation causes depreciation allowances to fall behind the cost of replacent capital. So companies must continue to borrow heavily to finance capital

spending. And companies that have already borrowed to the absolute hilt, must continue to borrow heavily to finance capital spending, moving to still higher ratios of external financing to internal funds.

"The windup," says Fromm, "is that many companies will cut capital spending plans. Then we may find that the resultant growth of the capital stock would be insufficient to sustain the growth of output that sociey desires."

The main evidence of those who foresee no capital shortage is the drop in the rate of return on invested capital that shows up in the chart on page 44. To some economists this suggests not that the supply of capital is short, but raher that the falling return has cut into the demand for capital.

Yet to jump from the fact that the rate of return on existing capital is falling to the conclusion that the return on newly invested capital is low may miss the entire point. In an analysis of the capital gap that has attracted wide attenion among economists. Federal Reserve Governor Henry C. Wallich argues that there is a critical difference between the two. He says that rapid technological change and shifts in relative prices—particularly the price of energy—which is reducing the return on old capital may, in fact, be missing the return on new investment.

The need for accelerated capital spending growth, therefore, seems fairly well established. And so is one other key proposition: that the funds to support capital spending growth will be forthcoming if, and only if, the federal government reduces its pressure on the capital markets.

THE NEED FOR A SURPLUS

The Bosworth-Duesenberry-Carron conclusion that the U.S. will manage to skirt a capital gap is heavily dependent on a federal budget surplus emerging in fiscal 1977. In their model, the surplus emerges for two reasons. Expenditures grow only slowly; federal spending on goods and services growing at only 7% a year and actually falling in relation to gross national product. They do not allow for any major new social programs. And while transfer payments for Social Security rise at 10.9%, total federal spending grows at 8.7% a year, lower than the growth rate of the past decade.

With spending under restraint, Bosworth, Duesenberry and Carron get surpluses, not because of major changes in government policy but because higher inflation combines with real GNP growth to boost revenues by 11.7% a year.

Should spending move up faster than these projections, however, the economy would be in trouble on anybody's assumptions. And since each new victim of the capital crisis immediately demands financial relief from Washington, the odds are very good that spending will move up faster than these projections. A study prepared for Labor Secretary John T. Dunlop indicates it will take major tax changes to generate enough savings to satisfy the demand for capital.

Says Don Conlan, a former Dunlop aide at the Cost of Living Council who initiated the study and who is now executive vice-president of Capital Strategic Services, a Los Angeles consulting group: "It's extremely unlikely that the financing techniques used by business in the past 5 to 10 years will do the trick in the next 5 to 10 years. Given the balance sheet deterioration we've already had in terms of the rising debt/equity ratio, it's questionable whether the public will be willing to hold as much paper as business will have to float, if there is no policy action to improve cash flow."

And that is the nature of the crisis: the need to invest more to keep the economy growing, but also the strong likelihood that given the tax laws and corporate balance sheets as they are, and the economy as it is likely to be, there will not be enough capital to meet those investment goals. Some factors in this equation must change or the U.S. economy of the late 1970s and the 1980s will be unlike anything the American people have seen in nearly four decades: an economy marked by slower growth, higher unemployment, and fewer fulfilled promises for nearly everyone.

JET INDUSTRIES LTD.,
Seattle, Wash., September 12, 1975.

Mr. DENNY MILLER,
c/o Senator Jackson,
Old Senate Office Building,
Washington, D.C.

DEAR DENNY: Attached is self explantory copies of correspondence regarding an amendment I was too late in proposing for the House EV Bill which was passed a week ago. When I spoke to you on the phone in Seattle, I was confident that the Business Industrial Development Association was going to commit with

a 90% SBA guaranteed, shared by the Rainier National Bank and Royal Bank Trust Co. (N.Y.).

BID turned us down because our projections showed we would need more than the $350,000 guarantee. We are still trying to raise funds for production in Seattle. Based on our experience the Senate Bill should include: "The Administrator may make direct loans to electric vehicle manufacturers if funds are not available from conventional sources."

Thanking for your interest, I am

Sincerely yours,

A. FORBES CRAWFORD, *President.*
JET INDUSTRIES LTD.,
Seattle, Wash., September 12, 1975.

ALAN HOFFMAN,
Senate Commerce Committee,
Old Immigration Building,
Washington, D.C.

DEAR ALAN: In accordance with our recent conversation I enclose a memorandum covering an additional recommendation to the Electric Vehicle bill:

It is recommended that the following be added to the loan guarantee clause:

"The Administrator may make direct loans to electric vehicle manufacturers if funds are not available from conventional lending sources."

The mechanics of enabling an applicant to apply directly could be initiated after being rejected by two lending sources.

Hoping the foregoing is of some assistance, I am

Sincerely yours,

A. FORBES CRAWFORD, *President.*

Enclosure.

ELECTRIC VEHICLE BILL RECOMMENDATION FOR DIRECT LOANS TO MANUFACTURERS

The House Electric Vehicle Bill which passed on September 5, 1975 provides for the Administrator to guarantee 90% loans to qualified manufacturers of electric vehicles with a maximum maturity of 15 years.

This does not necessarily mean that lending institutions will have funds available. Tight money situations may result in banks and lending institutions giving priority to existing customers. In addition, some banks may not have the capital structure to assist a manufacturer in a small town.

An electric vehicle manufacturer had a recent experience of having a 90% SBA guarantee for a loan rejected by two banks because the manufacturers ultimate requirements were such that the SBA maximum guarantee of $350,000 would not supply enough funds. The manufacturer could not show the banks a definite source of a future additional $1,000,000 or more indicated as needed by their cash flow projections.

It is therefore recommended that the following be added to the guarantee clause:

"The Administrator may make direct loans to electric vehicle manufacturers if funds are not available from conventional lending sources."

NOTE.—The administration of direct loans and guarantees could be handled through existing SBA offices under guidelines set up by the EV administrator.

U.S. ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION,
Washington, D.C., September 9, 1975.

Hon. WARREN G. MAGNUSON,
Chairman, Senate Commerce Committee

DEAR MR. CHAIRMAN: On June 3, 1975, Dr. James Kane, ERDA's Deputy Assistant Administrator for Conservation, provided testimony before the House Committee on Science and Technology, Subcommittee on Energy Research, Development & Demonstration, on H.R. 5470, the Electric Vehicle RD&D Act of 1975. The bill passed the House in the significantly modified version of H.R. 8800 on Friday, September 5, 1975. My understanding is that the companion bill S. 1632, which is very similar to the original H.R. 5470, has been referred to the Senate Commerce Committee for evaluation.

It is my opinion that if enacted in their present forms, these bills would mandate a costly and premature program of questionable value. My views are corroborated in the June 17, 1975, letter on H.R. 5470 from Russell Train, Administrator, EPA, to Congressman Teague. Thus, I would like to reaffirm several points expressed in Dr. Kane's testimony.

The emphasis of the bills is on near-term demonstration rather than development of improved electric vehicles. A basic premise is that current lead-acid battery technology is adequate for a limited production of electric vehicles which would be acceptable substitutes for at least some of the applications of conventionally powered vehicles. For some applications, such as urban delivery operation, this is probably true.

From the standpoint of obtaining useful range and adequate performance to allow such vehicle to mix safely with present day traffic in typical highway environments, improvements in the lead-acid battery are needed. Present lead-acid batteries have limited lifetimes. When life cycle replacement cost is included with energy cost, this results in a higher operating cost per mile than a conventional vehicle used for similar purposes, even at fuel prices three to four times that of today. We feel that this higher operating cost would discourage the acceptance of electric vehicles. Improvements in battery technology must occur before electric vehicles have a good chance of being economically competitive. Until these developments are realized, it would be premature to mandate a large and costly demonstration program designed to show the attractiveness of the electric vehicle option.

In our opinion, a minimum of three to five-year program to develop advanced batteries would be necessary to provide vehicles with lower overall operating costs and thus the ability to gain public acceptance. This is the thrust of the ERDA's program which is described in Dr. Kane's previous testimony. We believe that any demonstration program should be delayed until battery development programs are able to provide an improved energy storage system that is more compatible with use in urban traffic patterns. Further, the scheduling of such a demonstration program should incorporate, in addition to times required for development of new technology, lead times adequate for Government contracting and also sufficient time to evaluate and use earlier results in subsequent phases.

Finally, the determination of the proper size of any demonstration fleet should consider a number of factors, including the capability for producing the new technologies involved. The numbers of vehicles specified in the bills appear somewhat ambitious in this regard. We believe that flexibility should be retained to permit the number of demonstration vehicles to be determined as the program develops.

While we generally support the basic goals of the bills, especially the endorsement of the need for a vigorous effort in research and development on energy storage technologies and vehicle components, we cannot support these bills in their current form. This position derives mainly from our concern that carrying out a demonstration phase too rapidly may hinder, rather than foster, acceptance of electric vehicles.

In conclusion, let me repeat that I wholeheartedly support the goal of developing non-petroleum propulsion options for transportation. The bills recognize the many advantages that will result from the use of electric or other stored energy vehicles. I fully agree that demonstrations are desirable to stimulate the interest of the general public. My only reservation is that in proceeding rapidly with current technology, we might not achieve the goal we both seek.

Sincerely,

ROBERT C. SEAMAN:, JR.
Administrator.

UNIVERSITY OF RHODE ISLAND,
Kingston, R.I., September 30, 1975.

Hon. FRANK E. MOSS,
Commerce Committee, U.S. Senate,
Washington, D.C.

DEAR SENATOR MOSS: I am responding to your letter of September 19 requesting my opinion concerning HR 8800 and S 1632.

Although there is undoubtedly a place for electrical vehicles in our society, in my judgment their use can be justified in only a few very special situations.

A serious effort to expand their use beyond these special cases would be, I believe, a serious error. Since the major impetus toward an expended use of electrical vehicles is conservation, particularly conservation of petroleum, I shall address this problem first.

Although a steam power plant, operating near its design load, is more efficient than a two or three hundred horsepower engine delivering thirty horsepower to propel a car at 55 miles per hour, a careful analysis taking into account losses in the transmission of electrical energy over power lines, in its conversion into chemical energy in a battery, its reconversion to electrical energy on discharge, and losses in the driving motor will show that the overall efficiency of the electrical car is no greater than that of the internal combustion engine powered vehicle. The advantage of the electrical vehicle, if any, is due not to a better overall efficiency, but to the fact that the electrical vehicles in use or under development are small, light, and underpowered relative to the cars with which they are compared.

The October 1975 issue of *Consumer Reports*, published by Consumers Union which arrived at my home today, has, fortuitously, an article on electrical vehicles giving test data on the Citicar, the only U.S. electrical vehicle sold in any volume for general use, and another on the Honda Civic, an efficient, relatively clean internal combustion engine vehicle imported from Japan. The data in these articles allow a comparison based on actual test results. The Honda was reported as giving 21 miles per gallon in city driving (based on actual road tests, not the standard EPA dynamometer test), while the Citicar required 14 kilowatt hours to cover 33.6 miles. Using the national average for central power plant efficiency and transmission losses, these numbers indicate that the Citicar used 4,400 Btu of primary energy per mile, while the Honda required 6,800 Btu per mile. It is well known, however, that mileage improves drastically as vehicle weight and horsepower are reduced. If we compare these two vehicles we find the following data apply.

	Honda Civic	Citicar
Weight (pounds)	1,795	1,303.0
Horsepower	53	3.5
British thermal unit per mile	6,800	4,400.0
Cost (dollars)	$2,879	$2,946.0

It seems reasonably safe to conclude that if the Honda were reduced by one-third in weight and by a factor of 15 in power to match the Citicar, it would demonstrate a greater efficiency in the use of primary fuel than the Citicar, and it would still have a range of hundreds of miles rather than the range of 35 miles or less of the electrical vehicle.

The engine powered vehicle has another distinct advantage over the electrical vehicle in that the waste heat generated by the millions of engines in use is rejected directly to air (through the radiator and exhaust pipe) in small amounts distributed widely over the landscape, hence is not a problem. Since it is generated in the vehicle, some of it can be usefully employed to provide heat during the cold months. In the case of electrical vehicles the waste energy generated is concentrated at the power plant, and thus becomes a serious disposal problem—resulting in the thermal pollution which has made power plant siting such a difficult and growing problem. Winter heat for the vehicle must then be supplied from new energy—a propane burner in the case of the Citicar.

But perhaps the use of nuclear energy to provide the electricity for electrical vehicles and thus save petroleum is sufficient reason for promoting electric cars. I believe the fallacy in the argument lies in the figures which indicate that fissionable uranium (U235) will be exhausted at about the same time as petroleum, and only the early development and widespread use of the breeder reactor will extend the nuclear age much beyond the year 2000. Unfortunately the breeder, for many reasons, is receding farther into the future, hence building a large fleet of electrical vehicles based on the hope that the breeder will be available when needed may prove to be a poor strategy.

Even if the breeder should be successful beyond our fondest hopes, I do not believe we can build the power plants that will be required to meet our needs even for the next 25 years, hence building residential and commercial buildings, electrical vehicles, and installing industrial processes that depend on these plants will generate insoluble problems within a relatively few years. I have described

this problem in some detail in an article in the August issue of "Mechanical Engineering." Several copies of the article have been distributed to Congressional offices by the American Society of Mechanical Engineers, and a copy is undoubtedly available in your office.

Let me look briefly now at a few other problems.

The Citicar tested by Consumers Union covered 33.6 miles on a simulated shopping cycle at an ambient temperature of 80°F. At this temperature it could only travel about 30 miles without rest periods. At 40°F its range was reduced to about 20 miles. Traveling at full speed (32.5 mph), on hills, or with the lights on also reduced the range drastically. With these short ranges, and a required charging time of at least eight hours, it is unrealistic to think that all or nearly all battery charging will be done at night during off-peak periods. For this reason a substantial number of electrical vehicles would increase the already unattainable requirement for additional central station capacity.

The Citicar will require new batteries after 400 to 600 recharges (11,000 to 16,000 miles) at a current cost of about $330 plus labor.

The Citicar does not meet Federal safety requirements for vehicles. The weight increase that would be needed to meet these requirements would add substantially to the first cost and operating cost of the vehicle, and reduce its already poor performance.

Electrical vehicles are assumed to be quiet. Consumers Union reported the Citicar to be the noisiest vehicle it tested this year.

Lack of emissions is cited as a major advantage of electrical vehicles. The emissions, of course, take place at the power plant, and we do not yet have sufficient solid data to know whether the sulphur dioxide emissions of the coal fired plant or the radiation and waste products of the nuclear plant are more or less dangerous than the widely dispersed carbon monoxide, hydrocarbons, and oxides of nitrogen of the internal combustion engine.

Although other points could be made, these may be sufficient to indicate some of my concerns regarding the impetus of the bills in question. I support the research goals of the bills, particularly with respect to research on new battery concepts, for it is this area which needs a major breakthrough in order to make electrical vehicles realistic. To push the use of currently, or soon to be available, models by a program of purchase, distribution, and testing would be, in my judgment, a mistake. If we are willing to put up with a 1,300 pound vehicle powered by a 3.5 horsepower engine, an engine powered car could be built which would be far cheaper and more energy efficient than any electrical vehicle in sight.

If you would like more detail on any of these points, or if I can be of further help, please call on me.

Sincerely,

LEWIS D. CONTA, *Dean*.

UAW,
Detroit, Mich., October 1, 1975.

Hon. FRANK E. MOSS,
U.S. Senate,
Committee on Commerce,
Washingotn, D.C.

DEAR SENATOR MOSS: This is in response to your letter requesting comments on legislation concerning research, development and demonstration of electric vehicles, particularly as set forth in H.R. 8800 and S. 1632.

It is imperative that federal encouragement, support and coordination of automotive research be provided. That is a point we have consistently emphasized in discussing the entire question of federal auto standards. For example, earlier this year, I testified before the Senate Commerce Committee on S. 499 and S. 783; many of the features of those bills were incorporated in S. 1883 as passed by the Senate.

Electric vehicles are certainly one of the possibilities that must be included in any such federal research activity. The danger is that legislation dealing only with that possibility creates the risk of fragmenting the research effort, and diverting funds that might be used more effectively on other projects. We previously have pointed out the fundamental need to assign responsibility to one government agency for coordinating these research efforts. That is necessary to assure that all promising developments are fully evaluated, and that

adequate recognition be given to areas in which conflicting goals have to be reconciled. Presumably some of this need for coordination would be met by the proposal in both bills to put the project within ERDA, but I urge the Committee to give careful consideration to this aspect.

As to the specific procedures that might best be used to develop electric vehicles, the Committee has already received some comments from Dr. David Ragone. As you may know, Dr. Ragone has been acting as a consultant to the UAW on automobile technology, and we have found his advice extremely helpful. While the comments, which he sent to your Committee on these bills, were not made on our behalf we believe that they identify important points that should be reflected in any electric vehicle development program.

Sincerely,

LEONARD WOODCOCK, *President.*

PATTON, BOGGS & BLOW,
Washington, D.C., October 9, 1975.

Senator FRANK E. MOSS,
Committee on Commerce,
U.S. Senate,
Washington, D.C.

DEAR SENATOR MOSS: Outboard Marine Corporation, 100 Seahorse Drive, Waukegan, Illinois, ("OMC"), has asked that I write to express its support in principal for H.R. 8800 and S. 1632, which would authorize a Federal Program of Research, Development and Demonstration, in the Energy and Research Development Administration ("ERDA"). This Program would be designed to promote electric vehicle technologies and to demonstrate the commercial feasibility of electric vehicles.

Since 1956, when it acquired the Cushman Motor Company, Lincoln, Nebraska, OMC has manufactured and sold "electric vehicles" as defined in the proposed legislation. These vehicles are generally for off-road use, and are utilized in turf maintenance, and in and around factories as personnel and burden carriers. Copies of current OMC brochures which depict these electric vehicles are enclosed.

As an established manufacturer of electric vehicles, OMC is familiar with the many technological and marketing problems that confront present and potential producers of electric vehicles. Based on this experience, OMC considers the adoption of a Federal Program of Research and Demonstration as vitally necessary to the design and manufacture of advanced electric vehicles and their acceptability by the general public.

We have reviewed the submissions to the Subcommittee on October 7, 1975, and wish to make one specific recommendation for amendment of the proposed bills. In our view, on of the major deterrents to the development of a commercially realistic, on-road electric vehicle has been the standards adopted by the National Highway Traffic Safety Administration ("NHTSA") pursuant to the National Traffic and Motor Vehicle Safety Act of 1966, as amended. At the present time, on-road electric vehicles simply cannot meet certain NHTSA standards, particularly those relating to crash-worthiness (the 200 series of standards). To date, five manufacturers have received exemptions from the more difficult of these standards. While NHTSA has shown a commendable inclination to grant exemption requested by electric vehicle manufacturers, we believe that the necessity of obtaining exemptions necessarily stifles electric vehicle technology and exvperimentation. Obviously, the lack of certainty as to the standards that will be applicable to a full manufacturing run of vehicles deter manufacturer commitments of substantial funds to development of commercially acceptable vehicles.

The proposed legislation does contain a requirement that NHTSA submit to Congress a report relative to the standards that should be applicable to electric vehicles within a fixed period. We do not consider this adequate. We urge that the Committee amend the proposals to require NHTSA to adopt, within sixty days of enactment, modifications of its existing regulations which would exempt any electric vehicle, designed for passenger car or multi-purpose passenger vehicle use, from any standard for which an exemption has been granted to any electric vehicle manufacturer. In other words, the current exemptions would become regulatory provisions available to all manufacturers without the necessity of application for an exemption. For example, the following exemptions are among those that have been granted:

(i) ***Standard 103: Electric Defrosting Systems:*** NHTSA granted Sebring-Vanguard, manufacturer of the electric CitiCar, an exemption from Standard 103 on July 10, 1975, (40 Fed. Register 29115) based on the claim that a low voltage electric heater and defrosting system has not been developed for use in small, lightweight electric vehicles.

(ii) ***Standard 206, Door Lock and Retention:*** NHTSA granted Sebring-Vanguard an exemption from this Standard because hinge load requirements cannot be met by a lightweight electric vehicle. (*Ibid.*)

(iii) ***Standard 214: Side Door Strength:*** NHTSA granted an exemption from this Standard as disproportionate to the weight of a small electric vehicle. (*Ibid.*)

(iv) ***Standard 114: Theft Protection:*** This Standard was found to be impracticable. (*Ibid.*)

Moreover, because of the importance of developing electric vehicles as an alternative to the internal combustion vehicle, the Subcommittee should amend the proposed legislation to provide that any additional regulatory provisions that would be applicable to electric vehicles would only become effective with the concurrence of ERDA. Such coordination of regulatory functions between NHTSA (which is required to ensure safety of vehicles) and ERDA (which is required to develop alternate sources of power) is necessary to ensure orderly implementation of the objectives of the proposed legislation. Clearly, electric vehicle development cannot occur in an orderly fashion if there is a conflict between these agencies. Moreover, we anticipate that the information and knowledge developed by ERDA in the course of its activities under the proposed legislation should have a major influence on the development of standards applicable to electric vehicles.

We believe that the recommended amendments are not at all inconsistent with the objectives of the National Traffic and Motor Vehicle Safety Act. Obviously, NHSTA has concluded that the public interest commends adoption of the exemptions already granted and that the safety risks are outweighed by the need to develop fuel economical vehicles.

We respectfully request that this letter and its enclosures be included in the Record of the hearings on the proposed legislation. If there are any questions or if further information should be desired with respect to the matters discussed in this letter, kindly contact the undersigned.

Sincerely,

CHARLES O. VERRILL, Jr.

ALBERI, PERICONI & ALBERI,
Mount Vernon, N.Y., March 11, 1976.

Mr. ALAN HOFFMAN,
Committee on Commerce,
Dirksen Office Building,
Washington, D.C.

DEAR MR. HOFFMAN: We have been informed by the United States Government Printing Office that the final book on the Electric Vehicle testimony, which was given during the early part of October, 1975 in relation to the Electric Vehicle Research Development and Demonstration Act of 1975, has not been finally codified in the official book for this hearing.

As you know, at the hearing our client, on October 10, 1975, introduced its new "Modularized Electric Motor". Since then we have had the opportunity to speak to ERDA and NASA concerning this new motor. The treatment that was accorded our client by both these agencies was virtually insulting, in view of the tremendous potential of this new device.

However, both agencies rendered a report, the first report by NASA, dated February 10, 1976 by Mr. Harvey J. Schwartz, and the second report by ERDA, dated February 17, 1976 by Mr. Kenneth F. Barber. These agencies did not have sufficient expertise to evaluate this motor. However, they saw fit to do so anyway. If the only criticism that can be made against this new device is contained in these two (2) reports by both ERDA and NASA, then this motor can only be deemed a success by reason of the fact that their reports show little or no understanding of the basic concepts that are involved in this new motor.

Our client, Die Mesh Corporation, has analysed both of these reports. Therefore, we are attaching herewith a copy of both reports and the analysis thereof by Die Mesh Corporation.

We request that all of these documents be inserted into the Congressional Record in relation to the Electric Vehicle Legislation, as part and parcel of the Die Mesh Corporation testimony.

Thank you for your kind cooperation in this matter.

Very truly yours,

DANTE J. ALBERI.

Enclosure.

DIE MESH CORP.,
Pelham, N.Y.

ANALYSIS OF REPORT OF NASA DATED FEBRUARY 10, 1976 BY HARVEY J. SCHWARTZ AND REPORT OF ERDA DATED FEBRUARY 17, 1976 BY KENNETH F. BARBER CONCERNING THE BORELLO MODULAR ELECTRIC MOTOR

ANALYSIS

In order to understand the analysis of both ERDA and NASA, at the very outset it must be noted that prior to and during the attempted presentation of this new motor concept to both ERDA on January 7, 1976 and NASA on January 8, 1976, here was always present a negative undercurrent and attitude from the officials who were supposedly there to first learn what had been invented and only then go on to render an educated, factual evaluation. The President of Die Mesh Corporation. Mr. Dominick Borello, went to both ERDA and NASA in an attempt to inform them about this new motor. Distressingly, he was never even allowed to complete his presentation. The officials from these agencies continually attempted to discredit everything he tried to set forth, by not letting him give a complete presentation which is absolutely necessary in order for one to understand this new motor. Mr. Borello was continuously interrupted by textbook references that only applied to the conventional motor and the manner in which the electro and permanent magnets operated therein. They never took the time to try to understand how this new motor differed from the conventional motor.

Mr. Borello, on both occasions, exhibited a non-working mechanical model to illustrate the manner in which the magnets would operate. In both conferences there was absolutely no interest exhibited in this model. No questions were even asked thereof. If they had taken the time to examine this model or question it, they would have found that any arrangement for electro and permanent magnets and steel combinations could have been made, including the method used in a conventional motor. Therefore, it is obvious that they did not look at the model because both reports are totally silent on the aforesaid possibilities.

Mr. Borello could not present these possibilities even on his own because these people were so bogged down in their inability to understand the conventional motor and its internal workings. Further, they exhibited a surprising lack of knowledge concerning magnets. As a matter of fact, after these conferences were completed. ERDA was requested to bring in experts in magnets so that a proper evaluation could commence. This was never done.

As an illustration of what Mr. Borello was up against in his attempted presentation, the following is set forth:

1. At ERDA one official had to go to a dictionary to get the definition of BTU's.
2. Further, at ERDA during the discussion, no official was able to give the formula for horsepower, having to be told same by Mr. Borello.
3. At NASA Mr. Borello tried to explain that the new motor employs magnets in their most perfect configuration. When one official was asked if he knew what was the best position for magnets to be placed in to operate most efficiently, he said he did not know and had to get two ceramic magnets and test them for the best position before giving an answer, which untimately agreed with the manner in which the magnets are placed within the Borello Motor.

Further, at NASA Mr. Schwartz refused to accept the patent application, which Mr. Borello offered to leave. This would have fully explained the operation of the four motor designs, with drawings. The patent application was also supposed to be sent to Mr. Schwartz by ERDA, which was never done. This is apparent because Mr. Schwartz makes absolutely no reference to the patent application. Therefore, all that he had to base an evaluation on was a mechanical model which he did not look at, and a patent application which he refused to accept and a brief, handwritten synopsis by Mr. Borello, which was only set forth to briefly explain the simple form of the magnetic potential of electro and

permanent magnets, and not supposed to be a document on how to build an electro-magnet to work in a motor.

As a matter of fact, Mr. Schwartz' analysis on Page 7, last paragraph, states:

> "One mechanical loss which should be considered is the impact loss that occurs when the two magnets collide."

This can only indicate two things. One, he never even read the simple hand-written statement by Mr. Borello which he, however, conveniently attaches to his report and which unequivocally states on the first line of page 2:

> "None of these magnets will make contact but will retain an .010 space . . ."

Two, he was not even listening to what Mr. Borello was presenting because Mr. Borello stated on five separate occasions during the NASA conference that, "One of the unique aspects of this new motor is that a magnet chases a magnet and never makes contact."

Further, Mr. Schwartz makes another incongruous statement on page 5, last paragraph, when he states, ". . . it is not clear how this permanent magnet could be mounted on Mr. Borello's twelve inch discs." He is obviously referring to the hand-carried non-working mechanical model, which if he had listened to the presentation by Mr. Borello, he would have known that it was only a model showing the mechanical design and not intended to relate to the hand-written statement or to have permanent magnets attached to it.

It was apparent to Mr. Borello that Mr. Schwartz and company had their minds made up in advance. Prior to leaving the conference, Mr. Schwartz told Mr. Borello that the evaluation would probably be negative without any further research on his part. This is shocking from a government official.

Both reports are smitten with no facts to back up their claim, either from the magnet people or from their own simple unrelated experiments, that this new Motor will be less efficient than the conventional motor. The conventional motor's efficiency ranges from 30% to 80%, representing the motor running at the exact RPM and load that it is rated for. This does not include starting, overload and low voltage combinations which would further bring the efficiency down.

Concerning the efficiency of a motor, the number 746 watts should equal one horsepower as continually told to Mr. Borello by these officials. However, it was continuously attempted to be pointed out to them that a motor operating at 30% efficiency requires three times 746 watts which will total approximately 2500 watts in order to equal one horsepower. If the conventional motor could reach 80% efficiency under ideal conditions, it would require approximately 900 watts in order to equal one horsepower. It should be apparent by the range of wattage required, that 746 watts equal one horsepower is an erroneous number.

The constant claim of both ERDA and NASA to Mr. Borello at these conferences was that the concept of 746 watts equally one horsepower is a Law of Physics. Both ERDA and NASA were repeatedly requested to supply the precise method upon which the 746 watts was developed to produce one horsepower in magnetic force (*and not heat*). They could not supply an intelligent answer to this question.

It must be noted at this juncture that the answer to the aforesaid question is directly related to efficiency in a motor using magnetic force, such as the Borello motor.

The uniqueness of the mechanical design of The Borello Motor will allow the use of any type of magnet combination or design conceivable to show the full potential of a magnetic force in a rotating machine. The concept of The Borello Motor is to use the fuel which is the MMFS to its highest efficiency.

Both ERDA and NASA are laboring under a misconception when they both state in their reports that The Borello Motor claims to "produce more energy than it takes in". This further shows a complete lack of understanding by these agencies. The claim of this new device is clearly that "*it is more efficient in the use of the fuel (MMFS)*", thereby utilizing the available energy to its full potential. There is nothing magical about a magnetic force in a conventional motor or out of a conventional motor. The only available force is the one that the conductor supplies. Therefore, the conventional motor is not adding anything to the force, but is only attempting to utilize that force in the concept presently in use in the known state of the art. The Borello Motor uses the same MMFS in the conductor but only in a more direct and efficient way.

Another interesting point concerning these reports is that they both state that the Eriez Magnet Company, which they attempted to get information from concerning the efficiency of the eriez magnets in motion in this new motor, could not supply such information. As stated in the ERDA report on Page 2:

"They (Eriez) replied that to theoretically determine the efficiency was an extremely complex problem, involving electric and magnetic transient circuit techniques. It's solution required data, such as time constants and values of instantaneous inductance which they did not possess."

In spite of not being able to obtain this absolutely essential information, prior to any intelligent and definitive evaluation, both these reports go on to render a "Textbook Theoretical Analysis" which can only be considered valueless. Further, these reports attempted to give reasons why it is impractical and almost impossible to make useful combinations of electro-magnets operating with permanent magnets and electro-magnets operating wih electro-magnets in The Borello Motor. They say this in spite of the fact that even the conventional motor, which they espouse the magic of, must use these exact combinations to work. This is absolutely ridiculous in view of the fact that these problems were solved ninety years ago.

Both of these evaluations very carefully and conveniently fail to state even one of the advantages of The Borello Motor, as set forth in the paper titled, "The Borello Modular Electric Motor", dated February 27, 1976 attached hereto, not to mention the fact that this new motor is modularized, which is unique in itself. Please refer to the aforesaid attached exhibit describing this new motor and its advantages.

In observing exactly how this entirely new motor operates. it is extremely important to realize that many magnet companies in this country have been continuously attempting to utilize the enormous power of both their electro and permanent magnets to make a better motor. The principle reason why they have not been successful to date, after numerous years of research, is that they have attempted to use their magnets in a reciprocating motion, rather than the circular motion employed by The Borello Motor wherein a magnet chases a magnet without ever making contact.

At a time when our country finds itself in an energy crisis of monumental proportion and ERDA and NASA are "grabbing at straws in the wind" to improve energy efficiency, even by a mere 1%, the negative attitude displayed by both of these agencies should be condemned and further investigated by Congress who has entrusted these people with the responsibility of finding true potentials for energy savings and not the boondoggles that they have wasted billions of dollars on.

Finally, it is requested that both of these reports be evaluated by technically qualified persons with practical experience in both motors and magnets. After this evaluation by these experts, it is certain that the analysis of the ERDA and NASA reports, as set forth herein, will be confirmed.

U.S. Energy Research and Development Administration,
Washington, D.C., February 17, 1976.

Mr. Dante J. Alberi, Alberi, Periconi and Alberi,
Lincoln Building, Mount Vernon, N.Y.

Dear Mr. Alberi: As requested in your letter of January 23, 1976, I am forwarding the results of our evaluation of the Die Mesh Power Amplifying Borello Electric Motor in the attachment.

As you will note in reviewing the evaluation, it is our opinion that Mr. Borello's claims for a power amplifying machine cannot be supported by fact. Moreover, we believe the claim of power amplification is in direct violation of the most fundamental law of energy conservation. In addition, we have attempted to show how we feel Mr. Borello is misusing the data made available to him by the magnet manufacturers to arrive at what we consider to be erroneous conclusions.

A second and independent evaluation of Mr. Borello's electric motor concept is being prepared by the NASA Lewis Research Center in Cleveland, Ohio, as a result of the meeting which I arranged between Mr. Borello and NASA representatives on January 8, 1976. The results of the NASA evaluation will be forwarded to you within the next few days.

As I indicated in my letter of January 20, 1976, and again during our telephone conversation on February 9, even though we do not feel the Borello motor fits within the near term objectives of the Electric and Hybrid Systems Branch, I am forwarding the Die Mesh proposal, patent applications and all correspondence relating to this subject to the Concepts Branch. They will submit the file to the Office of Energy Related Inventions at the National Bureau of Standards where still another independent assessment will be made.

Again I would like to thank you and your client, Die Mesh Corporation, for the interest you have shown in energy conservation.

Sincerely,

KENNETH F. BARBER,
Acting Chief, Electric and Hybrid Systems Branch,
Division of Transportation Energy Conservation, Office of Conservation.

Subject: Review of Die Mesh motor concepts.

Background

A representative of Die Mesh Corporation met with ERDA personnel on December 22, 1975 and January 7, 1976 to discuss his concept of an electric motor. His intended application of the device is use as a traction motor for electric vehicles. He also displayed a non-operable mockup of the device at each meeting to illustrate the method of operation. A somewhat different version of the mockup was brought to each meeting. At the first meeting, an unsolicited proposal was submitted by Die Mesh entitled, "Production of 1000 Borello Electric Motors for Application in Industrial, Commercial and Consumer Use." The unsolicited proposal contains a three sentence statement of work and a time table which describe a thirty six month program to produce and test 1000 motors at a proposed cost of more than $11 million. A patent application is attached to the unsolicited proposal and is intended to provide a description of the device. The patent application illustrates four versions of the device, but only one version is proposed for production, that shown in Figures 30 through 32 with accompanying text on pages 10 through 14. All versions employ principles of operation similar to those of a solenoid.

A number of claimed performance advantages are made for the device, both verbal and written. Some of these claims, made from time to time, are listed as follows:

1. The device is said to utilize one-fourth the current input of conventional motors for the same output, all other conditions being equal. When a comparison of this type is made with a conventional motor, the results show that the output power of the proposed device would have to be greater than its input power.
2. More energy is said to be delivered by the device than is delivered to it.
3. The device is said to be a "power amplifier" which can deliver four watts for every one watt delivered to it.
4. The device is said to be analogous to a solenoid where "the dissipation of comparatively little electrical energy, i.e., by the flowing of relatively small amperage current through the solenoid coil to generate the magnetic field thereof, a strong mechanical force or power stroke is achieved, during the magnetic pull of the solenoid plunger towards the coil." This is said to be the reason for the larger output power with respect to the input power.
5. The device is said to be comparable to an electromagnetic lifting magnet. Die Mesh discussions and "calculations" are based upon this comparison.
6. Improvements are said to be realized over conventional motors due to the re-orientation of the magnetic field with respect to the acted-upon magnetic material. Conventional motors are said by Die Mesh to possess a poorly functioning, inefficient magnet; they have rotors which "move merely past, but not through the field"; they contribute to "unpredictable electrical consumption," short circuits when stalled, "loss of directional power when starting with a load that causes counter-rotation, inability to readily change speed and horsepower output," excessive repair costs, "inefficiencies caused by back EMF and other current losses which may amount to 20 percent of applied current," and other problems.

Discussion

Claims 1, 2, 3—These three claims are quite similar. Since the device is claimed to produce more energy than it takes in, the claim is a direct contradiction of the first and second laws of thermodynamics. This fact is sufficient reason alone to realize that the device cannot perform as claimed and should therefore be dropped immediately from further consideration. However, it was agreed with Die Mesh that a more detailed analysis would be undertaken.

Claims 4, 5—Contact was made with Eriez Magnetics who supplied Die Mesh with technical brochures and data sheets describing their electromagnetic lifting magnets. Die Mesh used this data as the basis for their calculations. Die Mesh results show an extremely low input power in relation to the output power. Telephone discussions were held with members of Eriez Engineering and Re-

search departments. It was agreed during the discussions that the magnets operating as suggested below must have an efficiency of less than 100 percent. The sample operating problem as posed to Eriez was the use of one of their lifting magnets held ⅛ inch above a 1 inch thick plate of steel. The magnet is required to attract the steel plate to itself. Eriez research department was asked if they had any data that would indicate what the efficiency of the lifting magnet would be, operating in that manner. They replied that to theoretically determine the efficiency was an extremely complex problem, involving electric and magnetic transient circuit techniques. Its solution required data such as time constants and values of instantaneous inductance which they did not possess.

The research department contact said that input energy to an electromagnet is divided into two major components, energy stored in the air gap, equal to $Li^2/2$ (where L is the variable inductance of the circuit and i is the instantaneous current), and energy lost in the coil equal to i^2Rt (where i is current, R is coil resistance and t is time). These parameters vary as the steel plate changes position, vary with temperature, vary with the transient time and require laboratory measurement for a determination of their instantaneous values. Electromagnets are widely used statistically (as a kind of magnetic hook) and are not normally required to do mechanical work. This is reflected in the type of limited data that is available.

Some of the Die Mesh calculations involving an electromagnet show a result of 61 watts input per horsepower output, indicating an impossible efficiency of much greater than 100 percent. Die Mesh made an attempt at determining the input and output power of an electromagnet that attracts and repels magnetic material placed ⅛ inch from its pole pieces by utilizing data supplied by Eriez Magnetics. However, Die Mesh did not apply the Eriez data properly, which resulted in erroneous conclusions. The following paragraphs attempt to show how the data was misapplied.

The validity of the Die Mesh power output calculations requires that the weight of the steel plate must be equal to the initial force (5600 pounds) exerted by the set of magnets at a distance of ⅛ inch from the magnet. To aid in visualizing the problem, the dimensions of a one inch thick steel plate of this weight are 11.75 ft.×11.75 ft. The assumption by Die Mesh that the chosen electromagnet has the capability to attract and repel this mass over an amplitude of ⅛ inch at a frequency of 60 cycles per second is not correct. No time-constant information of this type was available from the magnet manufacturer. The maximum frequency at which the electromagnet could move the mass over the full amplitude could easily be two orders of magnitude lower than this assumed frequency. This arbitrary assumption is the primary reason that Die Mesh calculations show such a high output power.

Further, it should be realized that this electromagnet will not repel the steel mass when the current is reversed in its coils. If it is assumed that coil current flow in one direction produces a north polarity at the pole face, then a south polarity is induced in the steel plate thus causing an attractive force between magnet and plate. If the coil current is reversed, a south polarity is produced at the pole face and a north polarity is induced in the steel plate also causing an attractive force between magnet and plate. The proposed device is said to possess permanent magnet plunger arms. It should be noted that when the current in each coil of the device is reversed, the resultant magnetic field tends to demagnetize the surrounded permanent magnet plungers. The repeling force between coil and magnet is thus greatly reduced.

Additionally, the comparison of the Die Mesh device with an electromagnet, although such comparison is not completely valid, should be performed with an electromagnet having a steel plate of more practical design with dimensions more nearly approximating the dimensions of the plunger of the proposed device. In performing the analysis in this manner it will be seen that the steel plate of that design will be easily magnetically saturated. This means that the attractive force between the magnet and plate will be greatly reduced because the magnetic flux has been greatly reduced. This effect can be seen by referring to the "Test Data Sheet for Selecto Lifting Magnets" contained in the Die Mesh calculations and data booklet. The saturation effect is the reason that the values of "tear-off force" decrease in any one of the data columns as the thickness of the steel plate decreases. Because of this, the output power of the device will be much lower than the value calculated or, alternatively, the coil ampere-turns and resultant ...t power must be increased significantly to produce the claimed output power. ...nally, the input power to the coil of the electromagnet, cited in the Die Mesh

calculations, is a steady-state value. For a true value of the energy input to the coil, because it is operating in a transient mode, it is necessary to measure the instantaneous power over the time occurring between switch closure and steel plate contact with the pole face. The resulting power versus time curve must then be integrated with respect to time. The actual power input is quite different from the steady state value because of the changing circuit inductance.

Claim 6.—The claimed problems with conventional motors are misstated. A conventional DC series motor has the following losses: windage, friction, i^2R losses in the coils, commutator segments and brushes, hysteresis, eddy current and fan losses. Motors, such as the type operating in ERDA's experimental electric vehicles (10 Kilowatt input), are stated to have an efficiency of about 85 percent at their design point. Larger motors have efficiencies in the 90 percent to 93 percent range. It is expected that the Die Mesh device could not approach the efficiency of conventional motors for the following reasons:

ALBERI, PERCONI, AND ALBERI, *Lincoln Building*

I^2R.—In conventional motors, the magnetic flux exists almost entirely in steel, whose reluctance is low, except for the small air gap. In the Die Mesh device the magnetic flux exists largely in air whose reluctance is high. This means that many more ampere-turns are required to produce an equivalent flux and also means that I^2R power losses in the coils will be greater.

Windage—A brief comparison of the rotor of a conventional motor, with its relatively, smooth surface perpendicular to its rotation, and the Die Mesh device, with its paddle-like design, seems to indicate that windage losses will be much higher in the latter design.

Friction—In conventional DC series motors, friction losses occur in the two bearings and in the commutator/brush contact. In the Die Mesh device, several rotating elements are involved that must be attached separately to the shaft resulting in many more bearings. In addition, the one-way clutches utilized to interrupt the rotation of each individual element will produce a significant friction loss. These clutches are operated a number of times during each revolution of the shaft, continually engaging and disengaging their sprag or roller elements. The high frequency of operation contributes adversely to their useful life. It is expected, therefore, that the proposed device will exhibit a low reliability with respect to a conventional motor.

Conclusion

It is judged that the Die Mesh device cannot live up to its claims of superior operation, nor can it approach the operating characteristics of conventional motors. No evidence has been presented by Die Mesh to justify encouragement of this concept. The proposed device does not fit into the research, development or demonstration goals of the Electric and Hybrid Systems Program.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION,
LEWIS RESEARCH CENTER,
Cleveland, Ohio, February 9, 1976.

Mr. DANTE J. ALBERI,
Alberi, Periconi, and Alberi, Lincoln Building,
Mount Vernon, N.Y.

DEAR MR. ALBERI: Enclosed is a copy of our analysis of the Power Amplifying Borello Electric Motor which we have conducted for and provided to Mr. Kenneth Barber of ERDA. I hope this information will assist Mr. Borello in evaluating his idea.

Sincerely,

HARVEY J. SCHWARTZ,
Manager, Electric Vehicle Project Office.

BORELLO REVIEW

On Thursday, January 8, 1976, Mr. Borello of Die Mesh Corporation met with Harvey Schwartz, Frank Gourash and Ed McBrien of NASA to explain his new motor concept. Mr. Borello brought a conceptual model which consisted of two discs about a foot in diameter mounted on a single shaft and arranged and connected by one way clutches so that they could only rotate in one direction. The model did not include any electrical or magnetic devices, although their locations were indicated. The new motor concept was substantially different from the con-

cept reviewed previously as described in the letter from Harvey Schwartz to Kenneth Barber (ERDA), dated December 8, 1975.

Mr. Borello explained the operation as follows. On each disc would be located an electromagnet and a permanent magnet. Each electromagnet would be located adjacent to the permanent magnet of the other disc. When an electromagnet is energized so that its field aids the field of the other disc's permanent magnet, a force of attraction exists. Because of the one way clutch, only one of the discs may rotate. When the current in the coil is reversed, the fields are opposed and the force is one of repulsion. Again, because of the one way clutch, the disc that previously rotated is restrained and the other disc rotates. As the coil current alternates the discs continue to step. A similar action takes place between the other coil and permanent magnet combination. Any number of coil magnet combinations may be added. Mr. Borello did not present any information regarding the control scheme or power sources for the electromagnets.

We all agreed that the motor would probably work as described. We disagree with Mr. Borello regarding the efficiency of his motor. Mr. Borello's calculations indicate that his motor requires only 61 watts per HP (see Exhibit A). The claimed efficiency is $746/61 \times 100 = 1222\%$. If this claim were true the motor could be used to drive a conventional generator, which then could supply the 61 watts and still have enough power left over for other purposes. Mr. Borello brushed aside all attempts to discuss the theoretical impossibility of this claim by telling us that the proof lies in the data sheets of magnet manufacturers and that our conventional analysis methods were incorrect. The communication problem appeared to be caused by Mr. Borello's apparent misunderstanding of the technical meaning of the words force, work, energy and power. The meeting closed with our agreement to analyze his calculations and catalogue data in more detail, checking with his sources as required.

Page 1 of Mr. Borello's calculations (see Exhibit A) refers to 4 electromagnets weighing 139 lbs. each and having a pulling force of 1400 lbs. at ⅛″ spacing. This data corresponds to Eriez Magnetics Company Model SL–10 Electromagnet working in conjunction with a 1″ steel plate. (See Exhibit B) An attempt to obtain more information from Eriez was made on January 15, 1976. Mr. Al Amidon, Sales Manager, and Mr. Bill Benson, Chief Electrical Engineer, were contacted. They confirmed that the data sheets used by Mr. Borello contained static test data only. The data sheets are intended to illustrate the capabilities of their lifting magnets. Such items as electrical and mechanical time constants, inductance and other dynamic parameters were not available. This is not surprising since transient data or data where relative motion between the magnet and load occur is not important to electromagnet manufacturers. They confirm that the SL–10 magnet configuration is that of a pipe and a concentric rod. They also described the "tear off test" procedure as follows: the magnet is placed in contact with the steel load and spacer combination. The magnet is fastened to a scale which, in turn, is suspended from a lifting device. The magnet is energized and then lifted. The force just prior to tear off is recorded. We also discussed the reasons for the non-linearities of the test data and confirmed that the 228 watts shown is the I^2R loss when the magnet is cold. The cost of the SL–10 magnet is $467.

Because dynamic information is not available from Eriez, an attempt was made to generate the data. The starting point was to examine the Eriez SL–10 electromagnet in its normal mode of operation. Exhibit C shows a cross section of the magnet including the dimensions supplied by Eriez. Since 10¾ inches corresponds to the O.D. of 10″ pipe, it seems probable that the outer cylinder is, in fact, standard commercial pipe. Consequently, two trial designs using schedule 40 and schedule 60 pipe were made. The results are tabulated in Exhibit C. The only assumption made in the dimensional calculations was to make the magnetic cross sections approximately equal throughout the entire structure. Such an assumption tends to optimize the use of magnetic material. Mounting four magnets of this size on 12″ diameter discs may present some problems, but this was assumed possible for this analysis.

The next step was to calculate the flux density using the Eriez data sheet, which shows 1400# tear off force at ⅛ inch spacing. Mr. Borello uses this data point as the basis for his calculations. A convenient formula by Creamer [1] and by Matsch [2], gives the values of flux density tabulated in Table 1. From these values

[1] Creamer, W. J., *Elements of Electrical Engineering*, pg. 212.
[2] Matsch, L. W., *Electromagnetic and Electromechanical Machines*, pg. 25.

the total flux, air gap field intensity, ampere turns, and inductance may be calculated. The validity of the formula was checked by solving Slemon's problem 1.32.[3] The problem is of interest since it has the same magnetic structure as the Eriez magnet. Both Slemon's and Craemer's methods lead to the published answer. It might be noted that Craemer's book was published in 1948, Slemon's in 1966 and Matsch's in 1972.

Both the schedule 40 and schedule 60 calculations lead to a nearly identical value of inductance of 17.3 henries. However, the schedule 40 design had a calculated flux density of 138,000 lines/in^2 at contact. Since this value is above the saturation level of steel, schedule 60 is a better design. Even 117,000 lines/in^2 is a high value. At this level the device is non-linear and there is considerable magnetic leakage and fringing.

At this point, consideration may be given to the mode of operation suggested by Mr. Borello. Of primary concern is how fast can the magnet be cycled. Mr. Borello gives no indication as to how he would energize the magnet but that it would be done at a rate of 10 times per second. The simplest and probably the most efficient way is to connect the magnet to a D.C. source by means of a switch closure. More sophisticated forcing functions such as a decaying exponential or a high frequency sinousoidal or square wave generator might be employed to increase speed but at a probable sacrifice of efficency.

For purposes of analysis a step function of voltage, obtained by a simple switch closure was assumed. If no relative motion were to take place between the magnet and load, the current would build up exponentially according to the equation $i(t)=(V/R)\,(1-e(^{Rt-/L}))$. The L/R time constant is 17.3/76.7=0.23 seconds. Actually, as the load is attracted to the magnet, the inductance and time constant both increase. Exhibit D shows a normalized plot of both $Vi(t)$ and $i^2(t)R$ assuming constant inductance. The area under the $Vi(t)$ curve is proportional to the energy supplied by the electrical source. The area under the $i^2(t)R$ curve is proportional to the energy transformed into heat and lost to the system. The area between the curves is proportional to the energy stored in the magnetic field. These energies are expressed by the following equations.

$$\text{Energy input}=\int_0^T Vi(t)\,dt=\frac{V^2}{R}\left[T+\frac{L}{R}e^{-\frac{RT}{L}}-\frac{L}{R}\right]$$

$$\text{Heat loss}=\int_0^T R[i(t)]^2dt=\frac{V^2}{R}\left[T+\frac{2L}{R}e^{-\frac{RT}{L}}-\frac{L}{2R}e^{-\frac{2RT}{L}}-\frac{3L}{2R}\right]$$

$$\text{Magnetic energy}=\frac{1}{2}L[i(t)]^2=\frac{V^2}{R}\left[-Le^{-\frac{RT}{L}}+\frac{L}{2R}e^{-\frac{2RT}{L}}+\frac{L}{2}\right]$$

The objective is to obtain the maximum amount of mechanical work with the least expenditure of energy. The curves indicate that shortly after closing the switch most of the energy goes into the magnetic field. At times greater than several time constants virtually all the input energy is transformed into heat. The efficiency curve shows the ratio of magnetically stored energy to total input energy at any time. Since mechanical work must come from the stored energy, the efficiency curve sets an upper bound on the overall efficiency.

The curves also indicate that at any time say $T=0.2\ L/R$ the current has only reached 18% of its final value. According to Creamer's formula, force is proportional to B^2 (flux density, squared) which is proportional to current squared. For instance at $T=0.2\ L/R$ current squared is only 3% of its final value. Consequently, the magnetic force will be only 3% of its final value. In the case of the SL–10, 3% of 1400 lbs. is 42 lbs., indicating that the magnetic materials would not be efficiently utilized.

The basic differential equation which mathematically describes energy conversion is—

$$V(t)=Ri(t)+\frac{dL(t)\,i(t)}{dt}=Ri(t)+\frac{Ldi(t)}{dt}+\frac{idL(t)}{dt}$$

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[3] Slemon, G. R., *Magnetoelectric Devices:* Transducers, Transformers and Machines, pg. 99.

This equation is Kirchhoff's voltage equation around a closed loop. Multiplying the equation by $i(t)$ and integrating with respect to time gives

$$\int_0^T Vidt = R\int_0^T i^2 dt + L\int_0^T i(t)\,\frac{di}{dt}\,dt + i^2\int_0^T \frac{dL}{dt}\,dt$$

The term on the left in the input energy. The three terms on the right are respectively the energy transformed into heat, energy stored in the magnetic field and energy transformed into mechanical units.

The process of obtaining mechanical work from the stored energy is depicted graphically in Exhibit E, where magnetization curves for two airgaps are shown.

As the magnet is energized the current and flux linkage increase to point A. The energy stored in the magnetic field is proportional to the area to the left of the curve. The slope of curve is proportional to inductance.

$$W_{stored} = \frac{LI^2}{2} = \frac{N\phi I^2}{I2} = \frac{N\phi I}{2}$$

As the load moves the air gap decreases and the inductance increases until point B is reached. Two of the infinite number of possible paths are shown. The horizontal path in the upper picture represents instantaneous movement from point A to point B. The original stored energy is proportional to the area of the triangle OAC. The final stored energy is proportional to the area of the triangle OBC. The difference of the two areas which is the area of the triangle OAB is proportional to the energy converted into mechanical units. The two to one ratio of flux linkages was chosen to approximately correspond to the calculated flux ratio of the SL–10 magnet. As a result, 50% of the stored energy is converted to mechanical work. The remaining 50% must be either dissipated as heat or somehow returned to the supply.

The vertical path from A to B represents very slow movement. In this case additional energy is drawn from the supply. The additional energy is proportional to the area of the rectangle ABCD. The mechanical work is again proportional to the area of the triangle OAB. This mechanical work is equal to ½ the additional energy input. The amount of mechanical work done is greater but there is also more stored energy to be dealt with. The actual path the load will follow is somewhere between the two paths shown. The upper bound on mechanical conversion efficiency is 50% unless some very sophisticated control scheme is employed.

The final phase of the analysis is to include the permanent magnet in the design. Mr. Borello's calculations (see Exhibit A) refer to a 39 lb. magnet having a pulling force of 250 lbs. at ⅛″ air gap. This magnet data corresponds to Bunting Magnetic Company Catalog No. CH–717 (see Exhibit F). This particular horseshoe magnet is no longer available from Bunting, but was 8¾″ high, 10″ wide, and 1″ thick. The cost was about $200. As was the case for the Eriez Model SL–10 electromagnet, it is not clear how this permanent magnet could be mounted on Mr. Borello's 12″ discs. In addition, the horseshoe shaped permanent magnet will not magnetically couple well with the concentric poles of the Eriez Model SL–10. This magnetic mismatch precludes an analysis based on the particular devices referenced by Mr. Borello. Only a more generalized treatment is possible.

Exhibit G shows a typical hysteresis loop of permanent magnet material. Usually B (the flux density) is plotted against H (the magnetizing force), but plotting Φ (total flux) against NI (ampere turns) seems more appropriate here. The magnet is initially magnetized in a closed magnetic circuit by subjecting it to a magnetomotive force NI_{max}. The resulting flux is Φ_M. When the magnetomotive force is reduced to zero, the flux reduces to the residual value Φ_R. If upon removing the magnet from the magnetizing device, or if by removing a keeper, an air gap is introduced into the magnetic circuit the flux is further reduced to point A. If the air gap is eliminated by reinstalling the keeper, the flux will not return to the residual value, but will traverse a minor hysteresis loop to point B. Subsequent removal of the keeper will move the operating point back to A. As the operating point moves from A to B, the magnet does mechanical work and the energy stored by the magnet is reduced. As the operating point moves from B to

A, the mechanical system must supply the energy which will be restored in the magnetic field. The area of the minor hysteresis loop is proportional to the extra mechanical energy which must be returned to the magnet on each cycle. The average slope of the hysteresis loop is the same as the slope of the magnetization curve at Φ_R. Increasing the air gap has the same effect as subjecting the permanent magnet to a demagnetizing magnetic field.

In Mr. Borello's motor the permanent magnet is subjected simultaneously to the demagnetizing effects of both a varying air gap and an external field. For best utilization of material the operating point A should be near the knee of the magnetization curve. Under no conditions should the external field exceed NI_c or the magnet will be demagnetized.

A permanent magnet operating in conjunction with an electromagnet is shown in Exhibit H. In general, both leakage fluxs and the mutual flux are all functions of the magnet spacing. However, the mutual flux is much more dependent on the spacing than are the leakage fluxs. Without loss in generality the permanent magnet may be replaced with an equivalent electromagnet carrying a constant D.C. current. The problem then becomes one of calculating the force which is developed by two inductively coupled circuits.

With each of the flux paths there is an associated value of inductance. Assuming linearity $L=n\Phi/I=N^2\mu A/x$ where N is the number of turns on the coil, μ is the permeability, A is the cross section area of the flux path, and x is the length of the flux path. In the case of the mutual flux, inductance is inversely proportional to the magnet spacing. In the case of the leakage flux the spacing affects the effective cross section of the flux paths. A convenient formula for calculating the force in such a doubly excited system is given by Matsch.[4]

$$f=\frac{1}{2}i_1^2\frac{dL_{11}}{dx}+i_1i_2\frac{dM}{dx}+\frac{1}{2}i_2^2\frac{dL_{22}}{dx}$$

This formula is equivalent to the one previously developed for a single electromagnet. Here L_{11} and L_{22} are self-inductances which include both leakage and mutual components. All three inductance are functions of x.

If i_1 represents the constant valued current in the electromagnet which replaced the permanent magnet, and i_2 is the real current in the electromagnet, then the operation can be described as follows. When i_2 is equal to zero, the last two terms on the right equal zero and the attractive force is determined by the first term only. One of Mr. Borello's discs will rotate so as to make the air gap a minimum. As i_2 increases in such a direction as to set up a field opposing the field of the permanent magnet the second term on the right produces a negative force. Because of the strong dependence of the mutual flux on the spacing x, this second term soon predominates and the magnets are repelled. Mr. Borello's other discs will then rotate. As the current i_2 is reduced to zero the force again becomes one of attraction and the first disc rotates again. It is not necessary for the current i_2 to actually reverse for the machine to work. Reversing i_2 merely increases the attractive force.

Summarizing this review we believe that Mr. Borello's motor will run but its efficiency will probably be less than conventional motor designs. Exhibit D put an upper bound on the efficiency of storing energy. Exhibit E showed that only a part of the stored energy can be converted to mechanical work. In the example used, only 50% was converted, but this might be increased by ingenious designs which could return the energy to the source but would still always be less than 100%. Magnetic losses have been ignored in this analysis. At high cycle rates, both hysteresis and eddy current losses are important in both the permanent and electromagnets. Eddy current losses may be reduced by laminating the magnetic structure. This will increase costs. All mechanical losses were also neglected as were mechanical time constants. One mechanical loss which should be considered is the impact loss that occurs when the two magnets collide. The impact may cause deteriorization of the permanent magnet. The ideal control scheme appears to be one in which a large current suddenly flows in the magnet until the disc starts to rotate. The current should then decrease as the air gap decreases. No control methods were suggested in Mr. Borello's presentation.

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[4] Matsch, L. W., Electromagnetic and Electromechanical Machines, pg. 62.

ELCAR CORP.,
Elkhart, Ind., March 26, 1976.

MR. ALLAN HOFFMAN,
Senate Committee on Commerce,
Dirksen Senate Office Building,
Washington, D.C.

DEAR MR. HOFFMAN: In accordance with your telephone conferences with our counsel, Peter A. Greenburg, I am transmitting to you under cover of this letter, a pro forma cash flow analysis, balance sheet and profit and loss statement for the production of a four passenger electric vehicle such as the one for which Elcar is now tooling. Because Elcar has been planning and is now ready to commence the production of such a vehicle, we have compiled current cost information which should be of use to your committee in determining the proper parameters for loan guarantees which will accomplish their objective of facilitating the production of electric vehicles by qualified prospective small manufacturers. The purpose of this presentation is simply to give your committee an understanding of the costs and cash flow which may be reasonably anticipated by such manufacturers after the completion of the design phase and the development of an actual prototype which is ready for production. A handbill with a picture and basic specifications for the Elcar model for which these costs were compiled is also enclosed.

The financial information presented presumes that the sums required for the project are represented by $100,000 of paid in capital and a federally guaranteed 15 year loan of $3,333,333. For demonstration purposes the maximum loan permissible under the provisions of Section 11 of H.R. 8800 is presumed. Such a loan would be eligible for a 90% guaranty. The financial structure selected therefore depicts a hypothetical manufacturing enterprise utilizing to the fullest the loan guaranty program of H.R. 8800. This example is not reflective of Elcar's actual financial structure or plans. In order to reflect an amortization schedule consistent with the cash flow projections, it is presumed that no principal payments will be made until the end of the first year; that the interest accruing during the first year will be paid at the beginning of the second year, and that thereafter interest and principal would be paid in level installments over the fourteen year balance of the loan period.

More fully described, the three exhibits submitted are a pro forma cash flow for the initial twelve month period, a pro forma three year balance sheet, and a pro forma three year profit and loss statement. For simplicity the cash flow projection assumes that the full loan proceeds are taken out on the first day of the first month of the year and that all capital equipment is purchased outright on the same day. While all capital equipment would have to be procured at the outset in order for orderly production to begin, in any actual venture the loan proceeds would be drawn as required in order to minimize the accrual of interest. The cash flow projection was selected simply as being a good format by which the hypothetical venture could be pictured at its most critical stage. The total production forecasted for the first year is 3,950 vehicles. By the end of the first year production would reach 600 vehicles per month with one shift being in operation. The pro forma balance sheet and profit and loss statement presume that during the second year one shift would be utilized for a total production of 7,200 vehicles and that in the third year two shifts would operate to produce 12,500 vehicles.

A major assumption in the hypothetical is that each car is immediately sold and delivered upon completion and that there is never an ending inventory of the vehicles. The inventory items referred to in the balance sheet and the profit and loss statements are component parts, raw materials, and work in process. It is generally deemed desirable to maintain a one month's supply of materials to minimize the possibility of production being interrupted by causes beyond the manufacturer's control. No consideration has been given to factors such as seasonal demand for vehicles and possible dealer stock piles.

An advertising budget of $100,000 per month is presumed from the very commencement of the enterprise. This is deemed necessary because of the basic need to acquaint the public with the very existence and utility of electric vehicles as well as with the product of the particular manufacturer. Substantial sums must therefore be devoted to what is normally termed institutional advertising.

Many minor items included in general categories in the exhibits are generally known to be proportionate to manufacturing activity in accordance with known standards. Increases in wage rates, cost of materials, and overhead due to intion would cause a corresponding increase in the price of the product and

would not effect the validity of the presentation. It is presumed that accounts payable, accrued expenses and current liabilities will remain constant so that these are not a factor in production planning. Wage rates are those prevailing in smaller cities in the midwest.

Normally production tools and equipment used in this type of manufacturing are depreciated on a straight line basis over seven years if use is confined to a single shift. If more than one shift is employed depreciation is accelerated accordingly. The actual useful life of a given tool or piece of equipment may be considerably longer or shorter. Actual depreciation may be accelerated by a change in the product or method of production which curtails useful life.

It is important to consider the degree to which production can be increased without substantial additional capital investment. Production at the level of 7,200 units per year does not make the fullest possible use of the contemplated facilities and tooling. Production could be increased to 10,000 units per year with an increase in labor costs of 60% and without the need of a second shift. If production at a level in excess of 10,000 units per year is desired a second shift would have to be added. Manufacturing experience teaches that a second shift will function at a level of approximately 80% of the efficiency of a first shift. In this instance a second shift could be expected to produce approximately 5,400 units per year. A third shift could be expected to produce an additional 5,400 units per year so that the maximum capacity of the facilities contemplated is approximately 18,000 units per year. The additional labor expense incurred as a result of overtime or higher wages on second and third shifts is of small significance in that labor accounts for less than 6.4% of direct cost.

We feel it best not to speculate on the manner by which production may be increased beyond the 18,000 unit level or whether additional aid in the form of further loan guaranties would be required to implement such an increase. This would depend on many factors which are unknown at present, such as the degree of sophistication to be utilized in production and the desirability of developing facilities in more than one geographic area in an endeavor to take advantage of favorable local circumstances or minimize transportation costs.

The information submitted is only useful in informing the committee of the requirements of a small manufacturer which has completed its basic research and product development and is ready to commence actual production. The figure of $5,000 per month for research and development in the projections reflects the activity and expense allocated to product improvement and presumes the preexistence of a well designed vehicle.

Elcar is anxious to render all assistance possible in facilitating the passage of S. 1632 with appropriate loan guaranty provisions. Should you desire any greater detail or explanation concerning this presentation or any other information relating to electric vehicles or their production, please contact Peter A. Greenburg, Esquire, who will see that any request is expedited.

Very truly yours,

LEON G. SHAHNASARIAN, *President.*

Enclosure.

PRO FORMA PROFIT AND LOSS STATEMENT

	1st year	2d year	3d year
Sales	$11,350,000	$22,320,000	$38,750,000
Beginning inventory	0	1,770,500	1,270,500
Purchases	11,645,500	17,500,000	31,000,000
Wages and other manufacturing expenses	898,240	898,240	2,086,000
Total	12,543,740	20,168,740	34,357,300
Ending inventory	1,770,500	1,270,500	1,020,500
Cost of goods sold	10,773,240	18,898,240	33,336,800
Gross profit	576,760	3,421,760	5,413,200
Expenses:			
Engineering	26,400	36,000	36,000
Selling	366,000	600,000	600,000
General and administrative	374,400	384,400	420,000
Advertising	1 200,000	2 000,000	2 000,000
Research and development	60,000	60,000	60,000
Interest expense	316,800	316,700	305,000
Depreciation	90,000	90,000	90,000
Total operating expense	2,433,600	3,487,100	3,511,000
Net profit or (loss)	(1,856,840)	(65,340)	1,902,200

PRO FORMA BALANCE SHEET

	End of 1st year	End of 2d year	End of 3d year
ASSETS			
Cash	$153,033	$580,943	$2,490,338
Inventory	1,770,500	1,270,500	1,020,500
Fixed Assets:			
Tooling, fixtures and equipment for frame, suspension, steering, and differential	375,000	375,000	375,000
Tooling, fixtures for body	140,000	140,000	140,000
Equipment final assembly	240,000	240,000	240,000
Office equipment	13,000	13,000	13,000
Total	768,000	768,000	768,000
Less reserve for depreciation	90,000	180,000	270,000
Total	678,000	588,000	498,000
Total assets	2,601,533	2,439,443	4,008,838
LIABILITIES			
Trade accounts payable	686,500	1,029,750	765,375
Interest payable	316,700		
Wages and withholding taxes payable	21,740	21,740	43,480
Income taxes payable			4,970
Total current liabilities	1,024,940	1,051,490	813,825
Loan payable	3,333,333	3,210,033	3,075,033
Total liabilities	4,358,273	4,261,523	3,888,858
NET WORTH			
Paid in capital	100,000	100,000	100,000
Earned Surplus	(1,856,740)	(1,922,080)	19,980
Total net worth	(1,756,740)	(1,822,080)	119,980
Total liabilities and net worth	2,601,533	2,439,443	4,008,838

PRO FORMA CASH FLOW FOR INITIAL 12-MONTH PERIOD

	1st month	2d month	3d month	4th month	5th month	6th month	7th month	8th month	9th month	10th month	11th month	12th month	Total for 1st year
Balance forwarded	0	$2, 239, 383	$1, 593, 633	$924, 483	$454, 833	$336, 683	$139, 433	$57, 883	$75, 003	$4, 183	($24, 267)	$23, 883	
Receipts:													
Paid in capital	$100, 000												$100, 000
Receipts from sales	0	0	361, 000	568, 000	931, 000	931, 000	1, 086, 000	1, 280, 000	1, 358, 000	1, 500, 000	1, 577, 000	1, 758, 000	11, 350, 000
Loan proceeds	3, 333, 333												3, 333, 000
Total	3, 433, 333	2, 239, 383	1, 954, 633	1, 492, 483	1, 385, 833	1, 267, 683	1, 225, 433	1, 337, 883	1, 433, 033	1, 504, 183	1, 552, 733	1, 781, 883	20, 608, 446
Disbursements:													
Material and freight	220, 000	430, 000	806, 000	806, 000	806, 000	879, 000	910, 000	1, 010, 000	1, 173, 000	1, 273, 000	1, 273, 000	1, 373, 000	10, 959, 000
Manufacturing wages and benefits	37, 050	46, 850	55, 250	62, 750	74, 250	80, 350	88, 650	83, 950	86, 950	86, 550	86, 950	86, 950	876, 500
Engineering and other manufacturing expenses	2, 200	2, 200	2, 200	2, 200	2, 200	2, 200	2, 200	2, 200	2, 200	2, 200	2, 200	2, 200	26, 400
Selling	30, 500	30, 500	30, 500	30, 500	30, 500	30, 500	30, 500	30, 500	30, 500	30, 500	30, 500	30, 500	366, 000
General and administrative	31, 200	31, 200	31, 200	31, 200	31, 200	31, 200	31, 200	31, 200	31, 200	31, 200	31, 200	31, 200	374, 400
Research and development	5, 000	5, 000	5, 000	5, 000	5, 000	5, 000	5, 000	5, 000	5, 000	5, 000	5, 000	5, 000	60, 000
Equipment purchases	768, 000												
Advertising	100, 000	100, 000	100, 000	100, 000	100, 000	100, 000	100, 000	100, 000	100, 000	100, 000	100, 000	100, 000	1, 200, 000
Total	1, 193, 950	645, 750	1, 030, 150	1, 037, 650	1, 049, 150	1, 128, 250	1, 167, 550	1, 262, 850	1, 428, 850	1, 528, 450	1, 528, 850	1, 628, 850	14, 630, 300
Ending balance	2, 239, 383	1, 593, 633	924, 483	454, 833	336, 683	139, 433	57, 883	75, 033	4, 183	(24, 267)	23, 883	153, 033	

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION,
Washington, D.C., October 3, 1975.

Hon. FRANK E. MOSS,
Chairman, Subcommittee for Consumers, Committee on Commerce, U.S. Senate, Washington, D.C.

DEAR MR. CHAIRMAN: This is in response to your letter of September 19, 1975, in which you request answers from the National Aeronautics and Space Administration to a list of specific questions on the bills S. 1632 and H.R. 8800.

As you know, NASA has done extensive work in areas of technology relevant to electric vehicle development. These areas include, for example, batteries, electric control systems, electric motors, materials, lightweight structures, etc. All of these technologies were employed in the development of the lunar roving vehicle, which had the characteristics of both a spacecraft and an electric vehicle. As an example of our current involvement in urban electric vehicle technology, NASA is funding a small demonstration of the application of nickel-zinc batteries in postal service vehicles. Also, ERDA and NASA have recently signed a Memorandum of Understanding under which we hope to cooperate closely with ERDA in this and other areas of mutual interest.

As indicated in our report of July 23, 1975, to the Committee, NASA's position on S. 1632 is that since ERDA would be the Agency primarily responsible for the conduct of the project envisioned by the bill we would defer to it for substantive comments. Our position on H.R. 8800 is the same.

The questions you asked are attached together with our comments.

If we can be of further assistance to you or the Subcommittee, please do not hesitate to call on us.

Sincerely,

JOSEPH P. ALLEN,
Assistant Administrator for Legislative Affairs.

Enclosure.

NASA'S ANSWERS TO QUESTIONS ON S. 1632 AND H.R. 8800

Question 1. What changes or additions would you make to S. 1632 or H.R. 8800?

Comment. As we have previously stated, since ERDA is the agency which would be primarily responsible for the conduct of the program envisioned by these bills we would defer to them for substantive changes or additions to the legislation. However, we do believe that any legislation in this area should recognize the need for flexibility for ERDA to formulate and carry out a project which is consistent with its overall research and development programs.

Question 2. What specific benefits do you see arising from such a demonstration program?

Comment. A premature demonstration could, in our view, result in a potentially unfavorable reaction from the public and could significantly delay further development or acceptance of electric vehicles. If legislation were to be enacted, it should be structured so that ERDA would be able to phase any demonstration to avoid such a result.

Question 3. Some electric vehicle proponents raise the concern that "premature" demonstration might lead to a negative public perception of electric vehicle potential due to alleged limitation cost and performance characteristics of existing electric vehicles. If you agree, how might the demonstration program be restructured to avoid this problem? If you disagree, please indicate why.

Comment. Rather than defining the scope of a demonstration program at this time, it would seem more important to set priorities and define technology goals and objectives. The decisions concerning the scope and nature of demonstration programs, as these technology goals are achieved, should be based upon the studies and recommendations of ERDA, the Department of Transportation, and interested industry representatives.

Question 4. Is one year a sufficient time in which to purchase and evaluate a baseline electric vehicle fleet of 200 to 300 vehicles, and develop performance criteria for purchase number 2? If not, what timeframes would you suggest?

Comment: In order to accurately and objectively establish the current commercial level of technology, it will be necessary to obtain vehicles from a number of manufacturers. This will require a reasonable procurement lead time and the preparation of objective evaluation standards prior to the conduct of actual tests. A key consideration in planning the evaluation program will be the opportunity to accurately identify limitations (both economic and technical) of existing

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Comment. Until initial technology advancements have been achieved, and reasonable numbers of demonstration units produced and tested by localized fleet operators such as the postal service or other organizations using vehicles from a central location, we do not believe that the scope of the infrastructure problems can be realistically defined.

Question 11. What are the performance characteristics of current technology electric vehicles? What improvements in lead-acid battery technology do you foresee in the next 5- and 10-year periods? What are the implications of these improvements for the performance characteristics and purchase and life cycle costs of electric vehicles?

Comment. Current electric vehicles have an effective year round operating range of about 30 miles in city traffic with a top speed of 40 to 50 miles per hour depending upon the vehicle. Operation at top speed reduces vehicle range by 40 to 50 percent. Acceleration is usually less than found in conventional compact cars. In general, the performance is suitable for normal city street traffic but is not compatible with the requirements imposed by most freeway or interstate traffic. Within 5 years, assuming an aggressive technology advancement program, we believe that vehicles could achieve consistent 50 to 60 mile ranges in city traffic, speeds up to 55 miles per hour, a performance capability equal to freeway driving for less range, and a battery lifetime of 4 years vs. the 1 to 2 years now available. Lower life cycle costs should occur due to the increased life of the batteries. Actual cost differences cannot be realistically estimated until the system design, performance requirements, safety consideration, and other cost items have been analyzed in considerable detail.

Question 12. In your opinion, what other batteries show promise of future use in electric vehicles, and on what time tables? What performance characteristics and costs will be associated with the use of these other batteries?

Comment. Three battery types offer substantial improvement over today's production lead-acid battery. These are an improved lead-acid, nickel-iron, and nickel-zinc. These batteries offer an improvement over current lead-acid batteries and when included in properly designed electric vehicle systems should provide the performance needed to meet virtually all urban driving requirements. Experts in the battery industry have predicted that these would become cost-competitive with today's traction batteries with sufficient volume and recycling of used batteries.

Advanced batteries, particularly those using alkali metals at high temperatures (lithium-iron sulfide, sodium-sulfur, etc.) will require 7–10 years to reach a comparable status. These are laboratory articles at present and many difficult technical problems remain.

Due to the present uncertainties about materials of construction and manufacturing procedures, cost estimates are not possible.

Question 13. What problems or constraints might arise in large scale manufacture of electric cars with respect to production equipment and manpower skills? What problems might be anticipated by electric vehicle manufacturers in the areas of materials or capital availability?

Comment. Current and projected concepts for electric vehicles do not appear to impose significant production equipment design or manpower skill problems. It is, of course, necessary that the electric vehicle system design be particularly concerned with assuring ease of manufacture from the standpoint of both production equipment complexity and the skill mix required.

Preliminary information indicates that until advanced alkali metal batteries are available, the introduction of more than 10 million total vehicles using batteries made of lead, nickel, and zinc would create shortages of these materials.

Question 14. Please state your views on the current and future applicability of safety standard and regulations to electric and hybrid vehicles.

Question 15. What steps might the federal government take to facilitate introduction of demonstration electric and hybrid vehicles into state and local government fleets?

Question 16. What institutional impediments do you see to the widespread introduction of electric vehicles?

Comment. NASA really has no experience or expertise upon which to base answers to these questions. These are significant questions which should be addressed by ERDA in formulating any research/demonstration projects in this field.

OFFICE OF THE SECRETARY OF TRANSPORTATION,
Washington, D.C., October 7, 1975.

Hon. FRANK E. MOSS,
Chairman, Subcommittee for Consumers, Committee on Commerce, U.S. Senate, Washington, D.C.

DEAR SENATOR MOSS: This letter is in response to your request of September 19, 1975 for the views of this Department and answers to your question pertaining to the subject matter of H.R. 8800, an act, and S. 1632, a bill to authorize in the Energy Research and Development Administration a Federal program of research, development, and demonstration designed to promote electric vehicle technologies and to demonstrate the commercial feasibility of electric vehicles.

With respect to H.R. 8800, Section 2 details the economic and environmental findings of Congress and suggests a Federal role in promoting development of electric and hybrid vehicles. Section 3 states a policy of encouraging R&D on electric and hybrid vehicles with the goal of introducing them into the fleet, and Section 4 defines key terms used in the bill. Sections 5 and 6 delegate project management to ERDA and define the responsibilities of management and objectives of the project. Section 7 establishes a timetable for developing performance standards and criteria and for production of electric and hybrid vehicles. Section 8 authorizes the introduction of electric and hybrid vehicles into the Federal Government fleets. Section 9 authorizes the Administrator to conduct research on incentives to promote use of electric vehicles and to assess long-range material demand and pollution effects which may be caused by electrification of urban traffic and on the applicability of safety regulations to such vehicles. Section 10 requires efforts to ensure that small business concerns and individuals have adequate opportunity to participate in the program. Section 11 authorizes loan guarantees to assist the commercial development of electric and hybrid vehicles and sets limits on the total amount available to a single qualified borrower. Section 12 outlines the contents of the semi-annual reports to Congress. Section 13 authorizes appropriations in the total amount of $160,000,000 for the period through fiscal year 1980.

S. 1632 substantially parallels H.R. 8800 but refers to electric vehicles only, does not provide for loan guarantees, and differs in some sections.

The Secretary's recent statement of national transportation policy noted our intention to preserve and maximize the unique contributions of the automobile while striving to increase its energy efficiency, economic and socially responsible use, and safety. The more intelligent and socially responsible use of automobiles is a matter of urgent and continuing concern.

The Department has been and is involved in a number of activities that are relevant to issues raised by the act and the bill. For several years, the Department has conducted studies and sponsored research related to the energy usage of automotive vehicles. Several of these studies have been evaluations of the present and potential capabilities of automotive power plants, including electric propulsion systems. The Department's automotive energy efficiency program, while assessing the improvements in fuel economy that manufacturers may make in their production vehicles over the coming years, has also supported evaluations of high performance batteries and of hybrid engines for cars. The National Highway Traffic Safety Administration (NHTSA) is supporting development of automobiles with substantial improvements in safety performance consistent with good emissions control and good fuel economy. The Department last year conducted with the Environmental Protection Agency a Congressionally mandated study of potential improvements in motor vehicle fuel economy. This year it is leading the interagency Task Force on Motor Vehicle Goals Beyond 1980. In addition, the Secretary is a member of the Low Emission Vehicle Certification Board (established by Sec. 212 of the Clean Air Act), which has considered electric vehicles exclusively.

Based on this specific experience concerning electric vehicles and our experience concerning automotive vehicles and their use, we have several observations.

First, electric vehicles available today are not competitive with conventional automobiles for reasons tied to the characteristics of available batteries. The law energy and power densities of lead-acid batteries put rather severe limitations on the range of electric vehicles. If electric vehicles are ever to be competitive with heat engine powered cars, it will be necessary to develop high performance batteries. Other special requirements of electric vehicles are relatively minor.

Second, vehicles which are to be used by a large segment of the motoring public must be evaluated in terms of the real requirements the market imposes on those vehicles, as well as the requirements imposed by Federal regulatory agencies. Electric vehicles designed for a segment of the automobile market should be compared with cars designed for that same market using the technology of the spark-ignition engine or using technology that would be available in the same time as the advanced battery.

Third, the potential benefits of electric vehicles appear problematical after close objective examination. For example, the overall energy efficiency (miles per energy unit) of electric vehicles on a typical urban driving cycle is somewhat uncertain but appears to be less than the energy efficiency of a car with spark-ignition engine designed to the same performance levels. Also, the environmental benefits are a tradeoff between less hydrocarbons, carbon monoxide, and oxides of nitrogen produced at street level and more oxides of nitrogen and sulfur produced by fossil fueled stationary power plants, or, if nuclear power plants are used, there would be other environmental effects.

Fourth, if large numbers of electric vehicles are to enter the fleet of cars on the road, they should offer the same minimum degree of safety performance as required of conventional vehicles produced in the same year. The occupants of electric vehicles would be exposed to much the same hazards as occupants of other cars and deserve the same degree of protection. In addition, safety hazards associated with battery must be given adequate consideration to hold the risk to the public to levels consistent with normal use of automobiles.

Fifth, substantial changes would be required in the infrastructure of sales, maintenance, fuel supply, etc., which support automobile use if electric vehicles should come into large scale use.

With respect to H.R. 8800 and S. 1632, we support the concept that ERDA should support research and development of batteries for electric vehicles and the development of hybrid power plants. It is appropriate for ERDA to support the R&D through the exploratory development and advanced development phases. It would not be appropriate for ERDA to develop advanced batteries to the point of commercial production. Commercial battery producers in private industry should retain that responsibility.

It is our view that the demonstration of electric vehicles by the Federal Government is premature by many years considering the maturity of electric vehicle technology. Moreover, it is not at all clear that the public would benefit enough from the use of electric vehicles to warrant the demonstration. The effect of the demonstration would be to stimulate the electric vehicle market, in effect, through an indirect subsidy to the producers of electric vehicles. Electric vehicles are already being produced for a small market and are being evaluated by a variety of users. If people are sufficiently convinced of the value of electric vehicles for their purposes, they can obtain the vehicles from suppliers. There does not appear to be good justification at this time for Federal intervention of this type in the electric vehicle market.

It also appears that the timetables specified in the bill and the act for purchase of electric vehicles and for the development of criteria may be too short to be carried out with effective results.

For these reasons, we believe the demonstration aspects of the act and/or the bill should not be supported.

Our answers to the questions you posed are enclosed.

The Office of Management and Budget has advised that there is no objection from the standpoint of the Administration's program to the submission of this report for the consideration of the Committee.

Sincerely,

JOHN HART ELY.

Enclosures.

Question No. 1. What changes or additions would you make to S. 1632 or H.R. 8800?

Answer No. 1. Our general observations on S. 1632 and H.R. 8800 are given in the text of our letter. Our comments on individual sections of these bills follow and apply to both bills except where one bill is specifically identified or a section is only in one bill.

Section 3(a). We disagree with the suggestion that it should be the policy of the Federal Government to demonstrate the commercial feasibility of electric vehicles or any other product. The marketplace is a better measure of the commercial acceptability and feasibility of products.

Section 3(b). If the Federal Government assumes an active role in promoting use of electric or hybrid vehicles and substitution of these for vehicles presently in use, adequate steps should be taken to ensure the safety of occupants through strict applicability of safety regulations now in effect for other vehicles.

Section 5(c). We believe that most of the activities described in this subsection are not the proper function of ERDA and that many are not the proper function of any Federal agency. The only activity properly the function of both the Federal Government and ERDA is that in paragraph (1) regarding research, which we support. The activities described in paragraphs (2), (3), and (4) should remain within the province of private business, especially with respect to the activities described in paragraphs (2) and (4). It is doubtful, in a context of changing technology, that anyone could develop an "optimal" overall design of lasting validity. Further, the Federal Government is no better and probably less qualified than the private sector to deal with the problem of optimal design. The activity described in paragraph (5) would be more appropriately assigned to DOT as it involves subject studied by the Department with respect to all modes of transportation.

Section 6. We support paragraph (1) given the precedents of government research assistance in a variety of different product lines. The primary barrier to the successful marketing of electric vehicles is the state of energy storage technology. We have no objection to paragraphs (2), (3), and (4), except that their close relation to transportation makes assignment of responsibility to ERDA rather than DOT questionable. For example, NHTSA is already examining, pursuant to title II of the Motor Vehicle Information and Cost Savings Act, the ease of diagnosis and repair of internal combustion engine vehicles; the Office of the Secretary is assessing methods to increase fuel economy of cars and trucks; and the Federal Highway Administration is studying traffic control systems to optimize their effectiveness.

Section 7. We oppose this section. Although there is some recognition elsewhere in the bills that the principal barrier to marketing the electric vehicle is the state of energy storage technology, this section implies that the barrier might be consumer ignorance instead. The evidence to support that notion is not apparent in the House report on H.R. 8800. This, apart from questions raised about the propriety of the Federal Government's becoming involved in the section 7 demonstration, there is strong reason to believe that the public funds for implementing this section would not be wisely or usefully spent.

As H.R. 8800 recognizes in section 7(a)(1) and (2), the first and second groups of vehicles to be purchased by ERDA would largely reflect the current state-of-the-art. Although section 7(a)(3) would specify the use of advanced components and designs, it would be prudent to provide ERDA with authority to determine that the final round of electric vehicles should not be produced if electric storage and drive train technology has not advanced sufficiently to make production of that round worthwhile. Even in four or five years, there can be no certainty that electric cars will have better batteries and drive trains leading to better performance and higher consumer acceptibility than existing vehicles.

In section 7(b), the Administrator is to develop performance "standards and criteria." In order to avoid confusion with safety, emission, and damageability standards, we suggest that the terms "requirements and criteria" be substituted for the terms "standards and criteria" wherever the latter terms appear in the act.

In a related matter, we prefer the version that appears in H.R. 8800 of the last sentence in section 7(b)(1). Unlike the Senate version of this sentence, the House version refers to vehicle safety as a matter concerning which ERDA would be required to consult with appropriate authorities, presumably including DOT in developing its safety criteria.

Section 7(d) of H.R. 8800 seems to reflect a judgment that the Buy America Act would not apply to the vehicles to be procured in the absence of the subsection. To the extent that section 7 seeks to stimulate the domestic electric vehicle industry, subsection (d) would reduce the flexibility of ERDA and might thereby reduce the chances of obtaining such vehicles.

Section 9(d). Since the National Traffic and Motor Vehicle Safety Act of 1966 entrusts DOT with sole Federal authority to regulate new vehicle safety and these bills deal only with setting safety criteria for a demonstration project, the purpose of the requirement in the House bill for DOT's submission of a report to ERDA regarding the "current and future applicability of safety st -

ards and regulations to electric vehicles" is obscure. It would be much more to the point to have ERDA make recommendations to DOT regarding the special consideration, if any, that should be given under the Vehicle Safety Act to electric vehicles.

Question No. 2. What specific benefits do you see arising from such a demonstration program?

Answer No. 2. One effect of the demonstration program would be to create an artificially increased demand for electric vehicles. Such demand would temporarily benefit manufacturers of electric vehicles and of parts therefor. Whether such stimulation would lead to advancements in electric power plant and drive train technology is unknown, but probably doubtful given the small size of the artificially increased demand. The demonstration would also create some added public awareness of electric vehicles and might generate some information on the maintenance and durability characteristics of electrical propulsion systems.

Although some promoters of electric vehicles credit them with substantial benefits in the form of reduced overall energy consumption, reduced petroleum consumption, reduced environmental impacts, or reduced costs relative to conventionally powered vehicles, the reality of these benefits is questionable. Specifically, a comparison of the overall energy requirements of battery powered cars and spark-ignition engine powered cars designed to approximately equivalent performance levels indicates little or no advantage to the electric vehicle.

Question No. 3. Some electric vehicle proponents raise the concern that "premature" demonstration might lead to a negative public perception of electric vehicle potential due to alleged limited cost and performance characteristics of existing electric vehicles. Do you agree or disagree that this danger exists? If you agree, how might the demonstration program be restructured to avoid this problem? If you disagree, please indicate why.

Answer No. 3. Both NHTSA and EPA have suggested that a demonstration program now might well be premature and counterproductive. Since even the third group of vehicles to be purchased under the House bill would very likely be similar to current electric vehicles, which are beset with problems involving cost, reliability, acceleration and speed capabilities, and range, the result could be a negative public reaction to electric vehicles. The public's current doubts about such vehicles would simply be reaffirmed. The possibility of injury to the cause of electric vehicles could be heightened if the criteria required by section 7(b) are used to create an artificial, unrealistic environment in which the electric vehicles to be procured are produced with substantially less safety protection than current internal combustion engine vehicles of subcompact or compact size. The difference under these circumstances between a demonstration electric vehicle and a safe electric vehicle might be substantial. A massive public information campaign about the demonstration vehicle might simply create false expectations about the electric vehicles that would be available to the public.

Question No. 4. Is one year a sufficient time in which to purchase and evaluate a baseline electric vehicle fleet of 200 to 300 vehicles, and develop performance criteria for purchase number 2? If not, what time frames would you suggest?

Question No. 5. Are the time schedules for purchases number 2 and 3 appropriate? Please explain.

Answers No. 4 and 5. The time schedules required in the act for the procurements appear to be too short to have their intended effect. Typically, Federal procurement procedures lead to periods of six months or more between the completion of a statement of work and the final approval of a contract by both parties. Six months to a year or more probably would be needed by a manufacturer between the time of contract approval and the delivery of the first vehicle for small volume production. In addition, test and evaluation of vehicles and subsequent development of revised performance requirements probably cannot effectively be accomplished in much less than 18 months.

Procurement and evaluation of a baseline fleet of 200 to 300 vehicles that have already been designed and are already in production possibly could be accomplished within two years of enactment. If the evaluation results in revised performance specifications that require additional engineering development, the contract for purchase number 2 might be signed by the end of the third year after enactment and delivery of the first vehicle might be possible a year later with an additional year needed for manufacture of the 2500 vehicles. Assuming that evaluation and development of revised performance specifications starts with delivery of the first vehicle of the second purchase, the contract for procurement of 5000 "advanced" electric vehicles might be signed by the end of the seventh year.

Question No. 6. What, in your opinion, will be the state-of-the-art in electric and hybrid vehicles within 42 months of enactment of H.R. 8800, assuming enactment during 1975? What Government policies would contribute most to commercialization of electric and hybrid vehicles?

Answer No. 6. We defer to ERDA for an assessment of the state-of-the-art of electric and hybrid vehicles within 42 months of enactment of H.R. 8800.

The Government policy that would contribute most to commercialization of electric and hybrid vehicles in the long run without direct subsidies is to support exploratory and advanced development of high performance batteries that have some chance of competing directly with general purpose cars.

Question No. 7. In addition to battery research, where should a Federal R&D program on electric and hybrid vehicles focus its efforts? How much funding should be provided for battery research and these other efforts during the next five years?

Answer No. 7. Most of Federal funds for electric and electric hybrid vehicle development should be allocated to battery research since the battery is the most inadequate part of the propulsion system. Vehicle systems design studies are also necessary. In addition, mechanical energy storage hybrid systems appear to hold promise for more efficient automotive power plants. Mechanical hybrid vehicles have mechanical rather than electrical drivetrains. They include flywheel energy storage and continuously variable transmissions.

The level of Federally sponsored R&D in this area should be consistent with the overall level of Federal R&D for advanced automotive power plants and with the potential benefits of successful development. We defer to ERDA, of course, for establishing these levels. It would be appropriate for a significant portion of the Federal funds for development of advanced automotive power systems to be allocated for improved energy storage systems—principally for advanced batteries and flywheel storage systems.

Question No. 8. Are there other vehicle technologies that offer comparable reduction in petroleum consumption and reduction of environmental impact to that of electric and hybrid vehicles? If so, is the special emphasis given to electric and hybrid vehicles in S. 1632 and H.R. 8800 justified? Please explain.

Answer No. 8. Vehicle technologies that offer comparable or greater reduction in petroleum consumption and reduction of environmental impact include redesign of vehicle structures to reduce weight, advanced catalyst systems, and engine control systems for the conventional spark-ignition engine, improved drive trains, and alternative engines, such as the stirling, diesel, and gas turbine engines. These energy saving technologies with pollution benefits are described in reports of DOT, EPA, ERDA, and NASA.

The special emphasis given to electric and hybrid vehicles in S. 1632 and H.R. 8800 is not justified. It would be more appropriate to provide adequate support for ERDA's program to conduct exploratory and advanced development of advanced automotive propulsion systems.

Question No. 9. How can an adequate manufacturing base and adequate competition be assured in electric vehicle production? Do S. 1632 and H.R. 8800 adequately address these needs? What changes or new provisions might be useful in this regard, if any?

Answer No. 9. The major issue for electric vehicles is whether their severe disadvantages with respect to conventional vehicles can be overcome by a development program so that they could compete successfully for the mass market. The manufacturing base for electric vehicles can be expected to evolve over time as the market for them expands. While H.R. 8800 provides for R&D on electric vehicles, for procurement of vehicles, and for financial assistance to manufacturers, the necessary development of electric vehicles is not given enough time to be successful. The artificial stimulus to the electric vehicle market provided by the bill does not ensure that electric vehicles will be competitive when the stimulus is removed. Our recommendation is to support exploratory and advanced development of high performance batteries through ERDA rather than to demonstrate noncompetitive electric vehicles.

Question No. 10. What infrastructure (for example, public or private recharging stations, maintenance and service facilities, etc.) must be developed to support the demonstration program called for in S. 1632 and H.R. 8800? What problems might be anticipated in establishing such an infrastructure?

Answer No. 10. The usual infrastructure of repair parts depots will be required and these will have to take vehicle distribution into account. If the vehicles are restricted to fleet use in specified and limited geographic locations,

the establishment and maintenance of electric vehicle service stations should not be too serious. If individual ownership on a geographically unrestricted basis is intended, the repair and maintenance problem could become difficult. It can be anticipated that the cost of these vehicles will be considerably greater than a conventional car and that maintenance and repair costs will also be significant. Altered insurance rates may also be encountered. An educational program for vehicle maintenance and servicing would have to be provided, as well as an educational program for users. The latter program would include information on maintenance, safety, realignment of driving habits to conform with performance characteristics, range limitations, recharge scheduling, etc. The infrastructure for maintenance and servicing would include technological education for maintenance staff, mechanisms for feedback of information on servicing to manufacturers (and ERDA), as well as the costs of facilities, parts, inventory, etc. If the program is to be effective, a detailed information retrieval and dissemination system will be required. Manufacturers, service stations, and users will need to keep careful records and a detailed data analysis program will be essential.

Question No. 11. What are the performance characteristics of current technology electric vehicles? What improvements in lead-acid battery technology do you foresee in the next 5 and 10 year periods? What are the implications of these improvements for the performance characteristics and purchase and life cycle costs of electric vehicles?

Answer No. 11. Electric vehicle performance is characterized in terms of range rather than the conventional definitions associated with internal combustion engines. In terms of power/weight, the typical internal combustion engine vehicle has values from 0.02 to 0.040 HP/lb. The typical current technology electric vehicle has values from 0.009 to 0.015 HP/lb. Thus, on a comparative basis, the electric vehicle shows rather low performance to the extent that power/weight ratios are a measure of performance.

An important caution is required with regard to the use of range as a criterion of electric vehicle performance. In actual practice, range is affected by driving habits, terrain, temperature, etc.

Current and projected performance characteristics of lead-acid batteries are: an increase in power density from 10–12 W-hr per lb to 16–20 W-hr per lb and power density from 10 W/lb to 20 W/lb. Cycle life is highly variable up to 2000 cycles. Projected cycle life is unknown. Improvements in energy density and power density will be achieved by such engineering techniques as thinner electrodes, larger amounts of active electrode area, lighter battery cases, etc. Projected ranges can vary from around 150 miles at a steady speed of 30 mph to a range of 50 miles in a metropolitan driving cycle specified by the Society of Automotive Engineers.

Cycle life is dependent upon depth of discharge, rate of charge and discharge, and mechanical and thermal effects due to overcharging.

Question No. 12. In your opinion, what other batteries show promise of future use in electric vehicles, and on what time tables? What performance characteristics and costs will be associated with the use of these other batteries?

Answer No. 12. Nickel-zinc batteries are anticipated to be developed in the time frame of five years. Zinc-chlorine batteries possibly could follow a couple of years later and the advanced high temperature lithium-sulfur and sodium-sulfur batteries are not anticipated to be completely developed much before 1985.

The driving range with nickel-zinc batteries should be at least double the driving range over lead-acid without range penalty during acceleration as would occur with lead-acid batteries. Zinc-chlorine batteries are expected to demonstrate a fourfold increase in range with excellent power performance. Costs are speculative. Based on raw materials, they should not be significantly different than lead-acid. Packaging costs, however, may be higher, particularly for the advanced sulfur types.

Question No. 13. What problems or constraints might arise in large scale manufacture of electric cars with respect to production equipment and manpower skills? What problems might be anticipated by electric vehicle manufacturers in the areas of materials or capital availability?

Answer No. 13. The most serious problem or constraint associated with a large scale manufacture of electric cars with respect to production equipment and manpower skills is that essentially an entirely new industry will be required to produce the required number of batteries. For example, if the battery ultimately used in electric vehicles should turn out to be of the lithium-sulfur type, it would be necessary to increase the present lithium production industry by about 1000

percent in facilities and manpower. The chromium required for the stainless steel in each lithium-sulfur battery may present problems since 51 pounds of stainless steel are required for each 300 pound battery. The U.S. does not have chromium resources. In addition, there would be employment skill shifts. Completely new manufacturing lines or suppliers would be required for electric motors and for electrical control equipment and tooling. Manufacturers probably would go toward the most advanced light-weight structures to reduce the weight of the vehicle to compensate for the weight of the battery. Vehicle fabrication methods and methodology would have to change to provide for the new structural methods and materials.

If the lead-acid battery is chosen as the energy source, the need for structural redesign and use of lighter weight materials would be even more acute because a lead-acid battery would be about five times heavier than a lithium-sulfur battery of equivalent energy content. In addition, the amount of lead required for several million cars annually might have a great impact on lead resources.

The amount of capital equipment required to build and assemble small urban electric vehicles could approximate $125 million for the engine assembly line producing about 400,000 engines per year and approximately $90 million would be required to establish a vehicle assembly line.

Question No. 14. Please state your views on the current and future applicability of safety standards and regulations to electric and hybrid vehicles.

Answer No. 14. In general, the Federal Motor Vehicle Safety Standards (FMVSS) should apply to all vehicles sold in this country. The application of some FMVSS's has been limited in some cases and exemptions have been granted in others. It would probably be an appropriate use of the exemption authority to facilitate the field testing and evaluation of electric vehicles. However, it is neither necessary nor desirable as a matter of public policy to follow this same approach with respect to electric vehicles sold to the public for personal or commercial use unassociated with field testing and evaluation of such vehicles. If electric vehicles are to have any discernible impact on national energy use or on air pollution, they must be produced and sold in large quantities. If electric vehicles become a significant portion of the overall vehicle population, they must not be permitted to subject their users or the rest of the public to undue safety hazards. With respect to persons other than users, a special danger peculiar to electric vehicles may be posed in that the relatively silent operation of such vehicles may contribute to accidents as a result of drivers' and pedestrians' failing to detect the presence of those vehicles.

It needs to be recognized that electric vehicles will have their own special safety problems. One of the most obvious is the possible problem of acid intrusion into the passenger compartment or spillage onto the roadway as result of a crash. High temperature batteries will pose different safety problems.

More than one-third of the annual highway deaths occur in urban areas and more than half of all highway deaths occur at speeds within the capability of existing electric vehicles. The concentration of these bills on urban vehicles does not, therefore, obviate the need for appropriate safety measures.

Since the electric vehicle will be operating in an environment dominated for many years by substantially heavier vehicles, adequate protection of the safety of electric vehicle users cannot be ignored. Even if the vehicle population were suddenly to be converted to vehicles of not substantially greater weight than electric vehicles, it should be carefully noted that riders in two subcompact cars that collide with each other at a particular speed are less safe than riders in two intermediate size cars that collide with each other at the same speed.

Question No. 15. What steps might the federal government take to facilitate introduction of demonstration electric and hybrid vehicles into state and local government fleets?

Answer No. 15. There is, of course, a wide range of incentives potentially available to the Federal Government with respect to actions it considers State or local governments should take. They include financial penalties for failure to take action, financial rewards, demonstration programs, etc. The question is what measures would be both appropriate and successful. An issue that immediately arises is whether State or local governments have vehicle applications that can be satisfied by electric or hybrid vehicles and how many such vehicles can be practically used. A minimum first requirement would be to obtain such information.

Question No. 16. What institutional impediments do you see to the widespread introduction of electric vehicles?

Answer No. 16. Assuming, for the moment, that an electric vehicle exists which could compete successfully with conventional vehicles if mass produced, then some of the institutional problems which could delay widespread introduction of that electric vehicle are: 1) need for a retailing network, 2) need for service and maintenance network, 3) lack of the equivalent of gas stations where batteries could be replaced or recharged. In reality, electric vehicles have not been developed to the point where they are competitive and their development should include compliance with FMVSS's and adequate protection of the safety of driver, occupants, other drivers, and pedestrians from any unusual hazards associated with electric vehicles.

U.S. ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION,
Washington, D.C., October 10, 1975.

Hon. FRANK E. MOSS,
Chairman, Subcommittee for Consumers, Committee on Commerce, U.S. Senate

DEAR SENATOR MOSS: Thank you for your September 19 inquiry concerning S. 1632 and H.R. 8800. I appreciate the opportunity to provide further information to facilitate Senate action on this legislation.

ERDA has recognized that the electric vehicle is an important option to consider as we attempt to minimize the environmental impacts of motor vehicles and reduce dependence on foreign oil. This option is being carried forward along with other important systems such as Stirling and Brayton cycle engines. Our high priority given to this area is explicitly stated in ERDA's plan and program, Volumes I and II of ERDA-48.

However, as expressed in my September 9 letter to Senator Magnuson (enclosed), it is my opinion that, in their present forms, H.R. 8800 and S. 1632 are inflexible in key aspects of the demonstration requirements and, if enacted, might mandate a costly and premature program. As we gain more knowledge about electric vehicles through our on-going program, collect more views of others, and evaluate the impact of the Bills more closely, we continue to reaffirm this initial evaluation. It is a view shared by many within ERDA as evidenced by Dr. Kane's testimony of June 3 on H.R. 5470 and Mr. Heller's upcoming testimony on S. 1632 and H.R. 8800. ERDA strongly supports the development of the electric vehicle option. The need for demonstrations will depend on the success of the research and development program and formulation of the demonstration programs should be left to ERDA. The nonnuclear Energy RD&D Act with the Energy Reorganization Act provides broad authorities to ERDA and, if we feel it is warranted, we will exercise this authority. Monies would be requested through normal appropriation channels.

The Office of Management and Budget has advised that, from the standpoint of the Administration's program, there is no objection to the submission of this information to the Congress.

Again, I would like to thank you for allowing us to comment on this legislation. If we can be of further assistance, please let us know.

Sincerely,

ROBERT C. SEAMANS, Jr., *Administrator.*

Question No. 1. What changes or additions would you make to S. 1632 or H.R. 8800?

Answer No. 1. The Senate Bill, 1632, is virtually the same as the original House Bill 5470. That House Bill was significantly modified in becoming H.R. 8800. We think that every modification made to H.R. 5470 is a step towards a more useful Bill. However, we judge that the demonstration, Sec. 7, as required in H.R. 8800 is still too much too soon and we would further modify that section. The specific modifications we would make in this regard are discussed below in Questions 3, 4, and 5.

Question No. 2. What specific benefits do you see arising from such a demonstration program?

Answer No. 2. Assuming proper scheduling, as delineated in questions 3, 4, and 5, and flexibility in numbers of vehicles to be demonstrated, such a program might have four major benefits. First, a usable data base could be formed. Second, public awareness of the capabilities and the limitations of the electric vehicle option could be increased. Third, much private activity, including increased R&D investment and cost sharing could be stimulated. This could accelerate the availability of the electric vehicle. Fourth, the demonstrations could identify tutional and other barriers to the use of electric vehicles.

Question No. 2. Some electric vehicle proponents raise the concern that "premature" demonstration might lead to a negative public perception of electric vehicle potential due to alleged limited cost and performance characteristics of existing electric vehicles. Do you agree or disagree that this danger exists?

If you agree, how might the demonstration program be restructured to avoid this problem? If you disagree, please indicate why.

Answer No. 2. A "premature" demonstration can lead to negative public perception which, in turn, can hinder the continued development of viable electric vehicle technologies.

The short times between the buys under the Senate Bill 1632 will preclude the opportunity for improvements in technology to be incorporated into each subsequent buy. House Bill 8800 provides more reasonable time periods to permit introduction of improvements in the third buy. Large scale demonstrations of only current state-of-the-art EV's can not serve well the intent of the proposed Bills and may lead to the dangers noted above.

The demonstration program needs to be restructured in two ways. Alter the timing as described under questions 4 and 5 below and leave to the Administration flexibility in the number of vehicles to be demonstrated. The vehicles obtained in the first and second purchase should be demonstrated under perhaps controlled situations, e.g., government motor pools, public utilities, military facilities, etc. Emphasis in the earliest purchases should be placed on EV's with the most potential for commercial markets. Lastly, more effort should be put into R&D to improve the EV cost and performance characteristics before encouraging widespread public use.

Question No. 4. Is one year a sufficient time in which to purchase and evaluate a baseline electric vehicle fleet of [illegible] to [illegible] vehicles, and develop performance criteria for purchase number 2? If not, what timeframes would you suggest?

Answer No. 4. One year does not provide adequate time. Time would be needed for contracting, production of vehicles, delivery, evaluation tests, in-use demonstration and analysis of data. Many vehicle manufacturers are still in the prototype phase and are not prepared for production. About one year would be required for purchase contracts and an additional six months to a year would then be required for receiving a sufficient number of the vehicles for test purposes. The development of performance criteria for the second purchase is essential for a well ordered program. We would estimate that it would take about 2 years to prepare and publish credible performance criteria.

Question No. 5. Are the time schedules for purchase number 2 and 3 appropriate? Please explain.

Answer No. 5. The time schedules in H.R. 8800 for the second two purchases are not realistic. The scheduling should allow: (1) Time for development of new improved technology, (2) Time for contracting and procurement procedures, and (3) Time for the government and private sector to evaluate and use earlier results in subsequent phases.

The completion of contracting for the second purchase within 15 months required in H.R. 8800 is too short because contracting would start before the expected publication of the performance criteria. The pacing elements for the second purchase must account for analysis of the first baseline demonstration test data and a test and evaluation phase to properly scope the second purchase demo., then incorporate improvements which are possible in the next phase. Another pacing consideration requires that at least six months lead time be planned between the first publication of performance criteria and initiation of contracting for the second purchase. This would be necessary to give the manufacturers a chance to adjust the manufacturing requirements for the improved vehicles.

Similarly, the initiation of the third purchase should be timed to permit analysis of results of the second purchase demonstration as well as to permit incorporation of advanced technology into the third buy; thereby encouraging a sustained market after termination of the field demonstrations.

These mean that accounting for the above considerations and those under Question 4, a schedule which suggests that the second purchase be contracted earlier than three years from enactment and that the third purchase be completed earlier than five years is likely to fall short of the objective of the Bills. At the same time fixed detailed demonstration milestones would limit use of technical options that are likely to develop. Flexibility in scheduling would encourage the use of optimum transfer of technologies into the demonstration system. ERDA would be prepared, under a flexible system, with a di[illegible]
to submit to the Congress a detailed annual report delineating the p[illegible]

Further, ERDA would seek to shorten the implementation and completion times of the EV evaluation program as delineated in the Bill.

Question No. 6. What, in your opinion, will be the state-of-the-art in electric and hybrid vehicles within 42 months of enactment of H.R. 8800, assuming enactment during 1975? What government policies would contribute most to commercialization of electric and hybrid vehicles?

Answer No. 6. Accurate estimating of technology improvements in these areas is quite difficult. If the ongoing battery/component development work is successful, we expect improved lead-acid batteries, higher efficiency components and electric vehicle systems with a better match of components to the system within 3½ years. The most important achievement would be life cycle cost reduction due to increased lead-acid battery lifetimes. Within the same period batteries such as nickel/zinc, iron/nickel, and possibly iron/air might be available for vehicle demonstration purposes. These batteries should provide about a 100% increase in operating range over the lead-acid battery.

Question No. 7. In addition to battery research, where should a federal R&D program on electric and hybrid vehicles focus its efforts? How much funding should be provided for battery research and these other efforts during the next five years?

Answer No. 7. The battery is the primary component on which to focus R&D efforts. It is generally agreed that strong Federal support is needed. However, improvements in any single component of the vehicle, such as the battery, cannot alone assure the development of a successful vehicle. The overall vehicle design is critical; other components are discrete entities and important in performance, i.e., maximum efficiency is set by the combined effect of all components; needs of users, manufacturing methods, materials requirements and impacts must be taken into account. The electric vehicle should be treated as a total system. Significant gains can be made in range and performance with existing batteries through vehicle designs and optimization of the electrical and mechanical subsystems for electric propulsion use.

A comprehensive R&D program would provide for battery development, mechanical and structural systems, electrical components and controls, recharging systems, auxiliary systems, thermal storage, heat engine and mechanical systems for hybrids, vehicle design studies, functional and economic analyses, technology implementation studies, and impact assessments. In the early phases the program focus should be on both all electrics and hybrids with a gradual shift to all electric systems in the latter phases. In the all electric area the program should specifically focus on: (a) improved vehicle designs with lighter weight high strength construction materials; (b) improvements in drive motors to increase part load efficiency and decrease weight; (c) better motor/control combinations to improve performance, life, and reliability; and (d) improved accessories and accessory drive methods to minimize energy drain on the main power source.

Such a comprehensive program, including battery research, is estimated to require about $150 million over the next five years. Of course, any Federal funding would also be contingent on overall budget considerations in reviewing national priorities. The focus of Federal R&D efforts beyond the battery would depend upon private undertakings which might be increased significantly in response to stimulus by strong Federal interest. Cost sharing on the R&D and in any demonstrations should be strongly encouraged.

Question No. 8. Are there other vehicle technologies that offer comparable reduction in petroleum consumption and reduction of environmental impact to that of electric and hybrid vehicles? If so, is the special emphasis given to electric and hybrid vehicles in S. 1632 and H.R. 8800 justified? Please explain.

Answer No. 8. Centralization of energy production can have negative as well as positive effects on the enviroment. The extent depends upon the distribution of fuel source, i.e., nuclear, coal, petroleum, etc. for locations where the EV's would be in use. A recent ERDA study examining the effects on urban pollution of introducing EV's in large quantities showed significant decreases in carbon monoxide, hydrocarbons, nitrogen oxide, and particulate emissions and a significant increase in sulfur oxide emissions. Also, it should be easier to control emission from electric powerplants with slow operating transients than from the individual sources operating on a transient basis with relatively poor maintenance. An assessment has not been made on a national scale of the relative impact of electric vehicles compared to the ICE with current emissions control technology applied.

Finally, the biggest advantage of the widespread use of EV's appears to be their compatibility with any energy source used at the central power station. This means that a switch from petroleum energy to sources in abundant supply domestically is possible with EV's.

Question No. 9. How can an adequate manufacturing base and adequate competition be assured in electric vehicle production? Do S. 1632 and H.R. 8800 adequately address these needs? What changes or new provisions might be useful in this regard, if any?

Answer No. 9. Adequate competition in the EV production area can be assured when the broadest possible spectrum of potential manufacturing companies are encouraged to participate. H.R. 8800 addresses this problem by requiring that small business concerns and qualified individuals have adequate opportunities to participate. The legislation would encourage this by requiring that a reserve of some funds for small businesses be made. Loan guarantee provisions are included in this legislation.

Question No. 10. What infrastructure (for example, public or private recharging stations, maintenance and service facilities, etc.) must be developed to support the demonstration program called for in S. 1632 and H.R. 8800? What problems might be anticipated in establishing such an infrastructure?

Answer No. 10. Provisions for service, maintenance, spare parts, and EV recharging would have to be developed to support the EV program of H.R. 8800. At the present time servicing operations for EV's exist only locally at the few dealer outlets where existing EV's are sold. Similar service centers would have to be established at each location where the EV's are to be sold, leased, or otherwise provided to participating agencies, companies, or individuals involved in the proposed EV demonstration program. This problem is further magnified if there were to be requirements to demonstrate EV's at numerous geographical areas in the country. Since current EV's (with lead-acid batteries) are limited to low charging rates (long charging times) and have short ranges, the service centers would have to be located in close proximity to EV usage, or mobile recharging or battery switching facilities must be provided. Improvements in energy and power densities of batteries would provide longer range and perhaps quicker charging to ease the extent of the problems.

Question No. 11. What are the performance characteristics of current technology electric vehicles? What improvements in lead-acid battery technology do you foresee in the next 5 and 10 year periods? What are the implications of these improvements for the performance characteristics and purchase and life cycle costs of electric vehicles?

Answer No. 11. The performance of current technology electric varies widely. Many current systems are constructed by converting existing auto bodies and chassis and these generally have a range between 25 to 35 miles and a top speed about 50 mph. Range can be reduced in practice by factors such as age of batteries, route profile including grades, maintenance level of batteries, state of charge, road conditions including rain, snow, concrete, gravel, etc., ambient conditions including wind and temperature, accessory requirements, number of occupants, driver habits and traffic conditions.

Another performance parameter is vehicle acceleration. Currently available vehicles provide very slow acceleration, usually 15 seconds or more to accelerate from 0 to 30 mph.

The performance characteristics of current electric vehicles are limited primarily by the battery capability which limits the driving range, speed, acceleration, and the required long charge time. The battery type used in most current electric vehicles is the lead acid golf-cart type. Cycle life of these batteries typically is about 300 cycles.

Some prototype vehicles have been designed from the ground-up with emphasis on light-weight construction. These vehicles with high battery weight have greater range capability, higher maximum speed and better acceleration. At present this is being achieved with the added penalty of higher initial and life cycle costs because of the larger number of batteries used. These vehicles also require special safety considerations. Lead-acid batteries for electric autos could be improved in two steps. With a strong development effort, we believe that a state-of-the-art lead-acid battery specially designed for electric auto application could be available in about 3 years. This new battery would be designed to reduce some of the problems with current off-the-shelf batteries; i.e. it would have a 33% increase in cycle life, a 27% improvement in specific energy and a fourfold increase in specific power. The projected improvements in lead-

acid battery technology in the next 5 and 10 year periods are shown in the attached Table 1. The major implication of these improvements is the extension of the driving range for the same battery weight, and some improvement in acceleration capability. The purchase cost and the life cycle cost are yet to be determined subject to the battery development. Realistic goals for this type battery are shown in Table 1.

TABLE 1.—DEVELOPMENT GOALS FOR LEAD-ACID BATTERIES [1]

	State-of-the-art			Advanced	
	Present [2]	Module demonstrated	In-vehicle demonstrated	Module demonstrated	In-vehicle demonstrated
Year [3]	1975	1977	1979	1979	1982
Specific energy, Whr/kg	26	33	33	50	50
Specific Power, W/kg:					
Sustaining	10	40	40	50	50
Peak	50	70	100	150	150
Cycle life	300	>1,000	>1,000	>300	>1,000
Cost, $/Kwhr	45	[4] 120	50	[4] 100	>50
Driving range, miles	20–35		45–55		50–70
Maximum speed (miles per hour)	50		60		60

[1] 3-hr discharge rate.
[2] Golf-cart batteries.
[3] Program initiation: October 1976.
[4] Preproduction.

Note: Driving range and maximum speed based on a 20 to 25 kWh battery propelling a 2500 lb compact vehicle.

Question No. 12. In your opinion, what other batteries show promise of future use in electric vehicles, and on what time tables? What performance characteristics and costs will be associated with the use of these other batteries?

Answer No. 12. Other batteries which show promise of future use in electric vehicles can be divided into intermediate and advanced types. Intermediate type batteries include nickel/zinc, nickel/iron, or metal/air batteries. These battery technologies could be ready in five years and provide a practical driving range of 100 miles. Advanced batteries showing promise, such as lithium/sulfur, sodium/sulfur, and zinc/chlorine, could be ready in eight to ten years. Performance characteristics of successfully developed batteries of these types should permit practical ranges of 150 to 200 miles. The developers of these batteries project life cycle costs competitive with those of conventionally powered vehicles.

Question No. 13. What problems or constraints might arise in large scale manufacture of electric cars with respect to production equipment and manpower skills? What problems might be anticipated by electric vehicle manufacturers in the areas of materials or capital availability?

Answer No. 13. Current and projected concepts for electric vehicles do not appear to impose significant production equipment design or manpower skill problems.

Except for battery materials, the large scale E.V. use requirement for copper, steel, plastics, and other common materials are modest in comparison to overall U.S. demand. Battery materials, however, represent a significant problem area and potential constraint on the number of E.V.'s that can be expected to be manufactured until advanced batteries (alkali metal) are available. Large-scale introduction of E.V.'s using batteries made of lead or nickel could create shortages of these prime materials and associated alloys and further increase reliance upon imported materials.

Question No. 14. Please state your views on the current and future applicability of safety standards and regulations to electric and hybrid vehicles.

Answer No. 14. ERDA, of course, defers to the Department of Transportation for the answer to this question since the National Traffic and Motor Vehicle Safety Act entrusts DOT with Federal authority to regulate new vehicle safety. Safety standards and regulations commensurate with the use of these vehicles must be applied.

Question No. 15. What steps might the federal government take to facilitate introduction of demonstration electric and hybrid vehicles into state and local government fleets?

Answer No. 15. H.R. 8800 would require the Administrator to arrange to introduce EV's into fleets of state and local governments and federal agencies,

as well as into individual and business use. The U.S. postal service, GSA, DOD and other federal agencies are specifically directed to introduce such vehicles into their fleets as soon as possible. Leasing, incremental cost payments, battery exchange and cost sharing arrangements could prove to be reasonable methods for reducing objections by federal and state agencies to EV use on the basis of procurement cost alone. Since such government fleets are generally serviced by rental garages, EV service and maintenance centers could be co-located with the normal fleet service center, further minimizing cost and maintenance-related vehicle usage interruptions. The Federal government could also provide for the installation of instrumentation necessary for test purposes, and for acquisition of the test data, in order to further minimize the cost and manpower impact on EV program participants.

Question No. 14. What institutional impediments do you see to the widespread introduction of electric vehicles?

Answer No. 14. There are a number of potential institutional impediments to the widespread introduction of electric vehicles (EV's). Perhaps the most important factor is limitation of industrial capital. Institutional investment costs required to implement major engine or vehicle changes are extremely large for this highly capital-intensive industry. High risk investments traditionally are not made, and vehicle innovations are made on a gradual basis.

A second class of impediments is related to existing Federal, state and local laws and/or regulations. For example, current roadway financing is largely supported by Federal and state gas taxes. If EV's were in widespread use, some other method of financing roadway upkeep and construction would have to be formulated. Price of electric power to the consumer is now regulated by Federal/state commissions. The widespread use of EV's would increase the amount of electric power used (as intended) and raise the issue as to new methods of pricing structure among various consumers of a given power company, particularly if EV's were largely recharged at night when such load-leveling techniques could have cost-saving benefits to the power companies.

Current DOT safety regulations with regard to impacts, crash-worthiness, etc., may have to be modified to take into account EV weight and performance limitations. Provisions for special EV hazards (electrolyte spills, exposed wires, high voltage, etc.) may have to be incorporated. Existing roadway design, signal light timing, provisions for merging traffic, traffic speed laws, etc., are all based on the capability of the conventional I.C. engine-powered automobile. The first generation of EV's is unlikely to have the same performance capability; modification of traffic laws and traffic flow aids would be required to permit EV use, at least in limited access areas. In addition, there may be local safety ordinances which prohibit the use of electrical outlets in areas exposed to public use. Such ordinances would have to be modified to permit use of safe, specially-designed recharging outlets for EV's if the public were to have the opportunity to recharge the vehicles at public streets, shopping centers, etc. There also may be a need for restructure of local laws such as the requirement that every vehicle have a gas tank and cap.

As in the case of the automobile manufacturing industry, the auto servicing infrastructure is a large and complex industry (personnel, service, maintenance, spare parts, etc.). As such, it requires investment capital, retraining of service personnel, new facilities, etc., to properly service EV's. It is most likely that its response to EV introduction would parallel that of the automobile manufacturers with the capability for EV introduction on a gradual basis only.

FEDERAL ENERGY ADMINISTRATION,
Washington, D.C., November 21, 1975.

Hon. FRANK E. MOSS,
Chairman, Subcommittee for Consumers, Committee on Commerce, U.S. Senate, Washington, D.C.

DEAR MR. CHAIRMAN: This is in reply to your letter of September [illegible], 1975, regarding H.R. [illegible] and S. [illegible], the *Electric Vehicle Research, Development, and Demonstration Act of 1975*. I trust that following information in response to your questions will be helpful.

Question Nos. 1–4. These questions deal with the problems [illegible] the actual demonstration of currently available electric vehicles [illegible] ment of state-of-the-art optimized electric vehicles. The [illegible] form appears to allow for a very thorough evaluation of [illegible]

nology. It is very important to have a comprehensive assessment of electric vehicle technology.

Although we feel that demonstrating state-of-the-art electric vehicles is important, it appears that some of the latitude of developing a sound demonstration program has been, denied the Energy Research and Development Administration (ERDA) by specifying the minimum number of electric vehicles which must be made under purchases numbered 2 and 3.

It is very difficult to estimate the length of time required by the procurements and demonstration required for the first two phases of the program. The complexity of the Government procurement process and the exact nature of the testing and demonstration process make the current time allowance appear to be the minimum that would be required for a comprehensive program. We feel that if such a program is enacted, at least 24 months should be allowed for the purchase and evaluation of the baseline electric vehicle fleet.

Question No. 6. Within 42 months of enactment of H.R. 8800, we feel that chassis for electric vehicles can be optimized. The lead-acid battery will be the only battery system available which will have sufficient energy storage capacity and lifetime without prohibitive costs.

Question No. 14. There are some safety standards which would not be applicable to an electric vehicle (for example, the safety standard which mandates the gasoline tank integrity in rear end collissions). We feel that all of the applicable safety standards for vehicles operating on public streets should apply to electric and hybrid vehicles operating in the same environment.

Question No. 16. We do not believe that there are any serious institutional barriers to the widespread introduction of electric vehicles. The most serious impediments to the introduction of electric vehicles will be the actual performance of the electric vehicles and their operating costs. If an electric powered vehicle can be developed which will be safe to operate, have adequate performance, and be economically competitive with current internal combustion engine automobiles, there will be no serious barriers to their widespread use.

Thank you for the opportunity to comment on this legislation.

Sincerely,

FRANK G. ZARB, *Administrator.*

U.S. SENATE,
COMMITTEE ON COMMERCE,
Washington, D.C.

DEAR ———: As you may know, the House of Representatives recently passed legislation concerning research, development and demonstration of electric vehicles. This bill, H.R. 8800, has now been referred to the Senate Committee on Commerce which is also considering S. 1632, the Electric Vehicle Research, Development, and Demonstration Act of 1975. I sponsored S. 1632 along with Senator Humphrey in May of this year.

The Senate Commerce Committee fully recognizes that the electric vehicle is an important option to consider as we attempt to minimize the environmental impacts of motor vehicles and reduce dependence on foreign oil. In order to facilitate Congressional action on this critical issue, Commerce Committee hearings on S. 1632 and H.R. 8800, which I will chair, have been scheduled for October 7 and October 10. To further facilitate Senate action on this legislation, I am also writing to you and other individuals and organizations knowledgeable on electric vehicles and related matters in order to obtain important background information for the record.

Attached you will find copies of S. 1632 and H.R. 8800, as well as a set of specific questions on this legislation. These questions encompass a range of issues which are likely to arise in consideration of these bills. Because of your interest and expertise in these matters, the Committee is very interested in having the benefit of your views. It is recognized that you may be more familiar with certain aspects of these issues than with others. Therefore, please feel free to answer any or all of the questions.

It will be appreciated if you could supply your answers to the Commerce Committee by October 2. Please address your response to me care of the Commerce Committee, Attention: Electric Car. Should you require any further information, please contact Dan Jaffe or Allan Hoffman of the Commerce Committee staff at (202) 224-9351.

Sincerely yours,

FRANK E. MOSS,
Chairman,
Subcommittee for Consumers.

res.

Question No. 1. What changes or additions would you make to S. 1632 or H.R. 8800?

H.R. 8800 would establish the following time table for implementation of the electric vehicle demonstration program:

(*a*) *Purchase No. 1.* Within one year of enactment contracts would be entered into for the purchase of "a reasonable number of electric vehicles for evaluation tests and initial in-use demonstration."

(*b*) *Initial performance standards*: Within one year of enactment, ERDA would develop initial performance standards and criteria for purchase number 2.

(*c*) *Purchase No. 2:* Within 15 months of enactment contracts would be entered into for the purchase of at least 2,500 electric vehicles meeting the criteria developed in (b).

(*d*) Operation and evalution of vehicles obtained under purchase number 2.

(*e*) *Revised performance standards/purchase No. 3:* Within 42 months after enactment ERDA would develop revised standards and criteria, and purchase at least 5,000 electric or hybrid vehicles exhibiting advanced performance characteristics.

(*f*) Operation an evalution of vehicles obtained under purchase number 3.

Question No. 2. What specific benefits do you see arising from such a demonstration program?

Question No. 3. Some electric vehicle proponents raise the concern that "premature" demonstration might lead to a negative public perception of electric vehicle potential due to alleged limited cost and performance characteristics of existing electric vehicles. Do you agree or disagree that this danger exists? If you agree, how might the demonstration program be restuctured to avoid this problem? If you disagree, please indicate why.

Question No. 4. Is one year a sufficient time in which to purchase and evaluate a baseline electric vehicle fleet of 200 to 300 vehicles, and develop performance criteria for purchase number 2? If not, what time frames would you suggest?

Question No. 5. Are the time schedules for purchases number 2 and 3 appropriate? Please explain.

Question No. 6. What, in your opinion, will be the state-of-the-art in electric and hybrid vehicles within 42 months of enactment of H.R. 8800, assuming enactment during 1975? What government policies would contribute most to commercialization of electric and hybrid vehicles?

Question No. 7. In addition to battery research, where should a federal R&D program on electric and hybrid vehicles focus its efforts? How much funding should be provided for battery research and these other efforts during the next 5 years?

Question No. 8. Are there other vehicle technologies that offer comparable reduction in petroleum consumption and reduction of environmental impact to that of electric and hybrid vehicles? If so, is the special emphasis given to electric and hybrid vehicles in S. 1632 and H.R. 8800 justified? Please explain.

Question No. 9. How can an adequate manufacturing base and adequate competition be assured in electric vehicle production? Do S. 1632 and H.R. 8800 adequately address these needs? What changes or new provisions might be useful in this regard, if any?

Question No. 10. What infrastructure (for example, public or private recharging stations, maintenance and service facilities, etc.) must be developed to support the demonstration program called for in S. 1632 and H.R. 8800? What problems might be anticipated in establishing such an infrastructure?

Question No. 11. What are the performance characteristics of current technology electric vehicles? What improvements in lead-acid battery technology do you foresee in the next 5 and 10 year periods? What are the implications of these improvements for the performance characteristics and purchase and life cycle costs of electric vehicles?

Question No. 12. In your opinion, what other batteries show promise of future use in electric vehicles and on what time tables? What perforance characteristics and costs will be associated with the use of these other batteries?

Question No. 13. What problems or constraints might arise in large scale manufacture of electric cars with respect to production equipment and manpower skills? What problems might be anticipated by electric vehicle manufacturers in the areas of materials or capital availability?

Question No. 14. Please state your views on the current and future applicability of safety standards and regulations to electric and hybrid vehicles.

Question No. 15. What steps might the federal government take to facilitate introduction of demonstration electric and hybrid vehicles into state and local government fleets?

Question No. 16. What institutional impediments do you see to the widespread introduction of electric vehicles?

[The above letter and questions were sent the the following:]

MECHANICAL TECHNOLOGY INC.,
Latham, N.Y., September 29, 1975.

HON. FRANK E. MOSS,
U.S. Senate,
Washington, D.C.

DEAR SENATOR MOSS: You and the other sponsors of Bill S. 1632 on electrical vehicles should be complimented and encouraged to see that a bill in this very important area of R&D is passed. I am attaching my remarks in answer to your committee's questions and also a copy of a letter to Dr. T. Moss which is applicable here, although it was prepared for the earlier versions of Bill H.R. 8800.

I am still very much concerned with the short time and low funding level in both of these bills. (My recommendations on this point are presented in the attached letter and modifications to this bill are in order.) I recognize the urgency of a viable electrical vehicle research and development program to insure a healthy national economy. I am afraid, however, that the proposed bill, which I am sure has good intentions, could produce negative results. Therefore, while I fully endorse electrical vehicle demonstration, I urge that a more realistic time table and funding level be considered. Secondly, it is very important that critical R&D in components and subsystems are not sacrificed at the expense of early demonstrations. A balanced program is, therefore, recommended with proper division and allocation of funds between R&D and demonstration. I consider this program of greater national importance than the space race resulting from Sputnik. Therefore, the program should receive strong endorsement from the President and Congressional leaders.

It is very important that this program receive high priority and management support in ERDA. (The Transportation Directorate within Conservation is a logical focal point for this program.) The various industries, governmental laboratories, universities, institutes, and individual should be encourage and motivated to attack the barrier problems. We cannot afford to rely solely upon the automotive industry to solve our transportation dilemma and economic crisis. Every effort should be exercised by ERDA to bring to bear all qualified resources to generate a viable U.S. electrical vehicle transportation industry that serves our country and exports electrical vehicles to foreign markets.

I sincerely hope that the bill, with the modifications to time, funding level and R&D funding allocation, will be passed soon so that we can embark on a vigorous program. I wish you and your co-sponsors every success in the passage of this very important bill.

Respectfully,

BENO STERNLICHT, *Technical Director.*

Enclosures.

Answer No. 1:

(*a*) Extend the demonstration period. (Refer to my letter of June 3, 1975, to Dr. Thomas Moss.)

(*b*) Increase the funding level.

(*c*) Demonstrate electric and/or hybrid vehicles.

(*d*) Earmark a certain percentage (not less than 30%) of the early funding level to R&D in critical component and subsystems.

(*e*) R&D in Energy Conversion must not be overlooked. Therefore, it should be identified in similar manner as Energy Storage (battery) is.

(*f*) The studies requested from the ERDA and DOT administrators are scheduled much too early. The danger, therefore, exists that they will not be technically sound.

(*g*) The purchase number 2 in H.R. 8800 is much too early. This will have the effect of very little difference between purchase no. 1 and no. 2. Purchase No. 3 is also scheduled too early. I fully recognize the urgency of this demonstration. It is unfortunate that it has taken us so long to recognize the need for this very important bill, but we should not try to accelerate the program to a point which will hinder its success. I feel that the timing in S. 1632 is much too short and while H.R. 8800 is somewhat longer, it is still not adequate. The level of funding is also too low to insure successful results in this critical area of our national economy.

Answer No. 2:

(*a*) The bill will act as a catalyst and will encourage existing and new industry, governmental labs, institutes, universities and individuals to contribute to this very important national challenge.

(*b*) New ideas and solutions to critical problems will emerge.

(*c*) We will be able to assess the status of electrical and hybrid vehicles in the U.S.A. and other parts of the world. We should be in a good position to insure our leadership in the automotive industry and catch up in the international race for electrical vehicle transportation. (This program with proper national support and emphasis could be compared to the U.S. space race. Economically, it is of much greater importance.)

Answer No. 3. I fully agree. It should be given more time; more R&D effort should be funded to insure viable demonstration. Multipilicity of sources should be funded. Each problem area (storage, energy conversion, vehicle integration, etc.) should be investigated by several competitive groups. Program management will be very important. It is essential that we become fully aware of our foreign competition in this field.

Answer No. 4. Minimum of two (2) years will be required. Several vehicle weights, vehicle types, missions, driving cycles, manufacturers, etc. must be thoroughly evaluated in order to establish a baseline for comparison and program guidance.

Answer No. 5. Purchase No. 2 will not benefit at all from Purchase No. 1 because it follows too early. Purchase No. 3 is also too early to incorporate the required R&D advances.

Answer No. 6. The demonstration as scheduled in the bill will prove that electrical vehicles are feasible. We know this today. The electrical vehicles will have poor efficiency, require considerable maintenance and have a very high life cycle cost. We should, therefore, initiate a high level of R&D effort. Provide financial incentives to electrical vehicle users. Appreciably increase taxes on petroleum; allocate part of the taxes to R&D effort on high efficiency vehicles and transportation powerplants that can operate on other fuels than petroleum.

Answer No. 7. The R&D effort must also include (besides energy storage in the form of battery research):

1. Energy conversion which includes transmissions, motors and controls.
2. Thermal and electrical engine developments to insure efficient and low cost hybrid propulsion systems. The thermal engine could also be used as a battery charger.
3. Vehicle—engine integration.

The R&D funding level should be at least 15% of the total demonstration program. The demonstration program should concentrate first on both hybrid and electrical vehicles and should transition in time to electrical vehicles, providing the technological barrier problems are solved.

Answer No. 8. The electrical vehicle has the unique feature of not requiring petroleum at all providing adequate nuclear, coal or solar energy is available for battery charging. It, therefore, offers unique opportunity for reduction in petroleum consumption and reduction of environmental impact.

Answer No. 9. H.R. 8800 provides assistance to manufacturers in the early stages when the amount of capital required is very small. The funding level should be considerably higher to insure program viability. It is also very important that a large number of manufacturers be financially encouraged. Some of these will with time undoubtedly disappear but industrial revolution and industrialization has shown that the strong will survive. There are many well known examples of governmental programs acting as catalysts, e.g., DOD and NASA support of the aircraft industry, ERDA support of nuclear and fossile fuel industry, etc.

Answer No. 11. Relatively poor performance from the standpoint of energy usage and reliability.

Answer No. 13. Refer to the attached letter of June 3 which discusses materials.

Answer No. 14. There is no reason to believe that the electric or hybrid vehicles will not be able to meet safety standards. This area, however, does require R&D effort in both energy storage (batteries) and energy conversion (transmissions/motors/controls). Both the House and the Senate Bills unfortunately ignore, by omission, the area of energy conversion which is of considerable importance to the success of the electrical vehicle. It should, therefore, be mentioned in order to emphasis the need.

MECHANICAL TECHNOLOGY INC.,
Latham, N.Y., June 3, 1975.

DR. THOMAS MOSS
Technical Consultant to Mr. Brown,
U.S. House of Representatives,
Washington, D.C.

DEAR DR. MOSS: Per your request, I am submitting a written statement on H.R. 6198.

The sponsors of Bill H.R. 6198 (originally H.R. 5470) on electric vehicles should be complimented for initialing the above bill. We all recognize that the health of our national economy is largely dependent on the automotive industry. Some of us have recognized the potential of the electric vehicle from a favorable balance of trade, conservation of liquid fuel, improved overall efficiency, greatly reduced emissions and noise, etc.

For some time I have been a strong advocate of the hybrid (heat engine/electric) and all electric vehicles as a highly viable system that can fulfill many of our required transportation missions (urban travel, etc.) and therefore, can represent a large share of future automobile markets.

I have expressed by views first, in a Product Engineering article published in February, 1974, expanded in an ASME paper #74–DGP–16, and later published in Mechanical Engineering in November, 1974. (This paper has received ASME honors in 1975). Excerpts from these articles are attached.

It is important to point out that the automotive industry has been under severe social, regulatory and economic pressure over the last decade. (See Fig. 1). All of these issues are additive and have put the automotive industry in a precarious postion. The next likely issue will be natural resources; this will be especially true if wrong material are selected for electric vehicles. (See Figs. 2 and 3, and Table I).

Most of today's batteries use lead and some of the advanced batteries use nickel. Both of these materials are in limited world supply and very little is found in the U.S. Already the automotive industry consumes very large percentages of these materials. Therefore, these materials are not viable for batteries in electric vehicles.

Batteries using zinc are also under development. While reserves for zinc are also limited in world supply, large quantities of zinc can be extracted out of sea water. Cost and electrical power availability are the only issues. These observations are cited only to point out a balanced well conceived program in electric vehicles is necessary in order to make the electric vehicle a viable business and mode of transportation. Just a wrong material choice for batteries can make the program worthless.

I have been seriously concerned with the lack of R&D effort in our country in this field and in fact have warned the automobile industry that their business is threatened by electric vehicles manufactured by their competitors in Japan. We recognize the seriousness of the Japanese competition in mass produced products. They have recognized the potential of the electric vehicle and have for some time conentrated their R&D effort on this subject. The bill, therefore, provides incentive and acts as a catalyst in our country, for which it is to be commenced.

I have, however, a very serious concern with one part of the proposed legislation. It centers on demonstration.

Demonstrations can have both positive and negative effects. A poor demonstration can have a major setback to a highly worthwhile endeavor. We all can cite many such examples. I feel that the proposed demonstration will have this effect.

My concern is based on personal knowledge of the present state of this technology, which is very limited and on the three years proposed which are much too short. The demonstration, therefore, will have to use poor components, which will undoubtedly result in poor overall performance and public acceptance. In addition, the R&D effort, which is very badly needed, will have to take second place to the demonstration program and this is also very dangerous. Demonstration overruns, resulting from problems, cost escalation, etc. will diminish the R&D effort. While I recognize the urgency and the value of demonstrations, we cannot easily make up for the lost time. It takes approximately nine months between conception and delivery; complex electromechanical systems, take an order of magnitude longer. Let's prevent abortion and also premature delivery which carries with it many unnecessary risks. The stakes are too high to take proposed demonstration shortcut.

It is also very important that we extend our options to include hybrid systems. These systems offer considerable potential and provide us with more time for the transition from the heat engine to the all electric propulsion. It provides the following modes of operation:

Heat engine propulsion for rural travel.
Electric propulsion for urban travel.
Heat engine and electric for acceleration.
Electric for renegerative breaking.

In addition, it provides an excellent means for recharging of the battery, both during driving cycle and also where recharging facilities are not available.

With time, as batteries improve, the heat engine will require less power and in the limit, it will become zero and be eliminated. The progress in the battery field will dictate this transition.

I would, therefore, like to recommend that the bill be modified to greatly increase the chance of our success. This can be accomplished by extending the period of the demonstrations and insure a vigorous national R&D effort.

The act should call for appropriations not to exceed $750,000,000 over a period of ten years. The first four years should be devoted to R&D in three critical component areas; batteries, transmissions and controls, and to hybrid and electric vehicle designs and integration. The next three years should be devoted to the demonstration of the hybrid and electric vehicles and continued R&D effort towards second generation of electric vehicles. At the beginning of the seventh year, the second demonstration should be initiated. In this case, the primary focus should be on the all electric vehicle.

To achieve this, the following funds should be appropriated:

$30,000,000 for fiscal year 1976.
$40,000,000 for each of the three years: 1977, 1978 and 1979.
$100,000,000 for each of the six years: 1980, 1981, 1982, 1983, 1984 and 1985.

Any amount appropriated shall remain available until expended, and any amount authorized for a given year, but not appropriated, may be appropriated for the next fiscal year.

The Highway Vehicle Directorate of ERDA's organization is already set up to manage this program. They lack, however, the necessary funds and some additional staff to conduct a vigorous R&D program.

These modifications to the bill will greatly increase our chances of success. The bill will be responsive to our national need. It will act as a catalyst for a new automobile industry and to some extent spurt our lagging national economy.

Sincerely,

BENO STERNLICHT, *Technical Director.*

[Excerpt from Article in Mechanical Engineering]

Industry has selected today. In fact, two of these options are being worked on by small R&D companies.

It is somewhat disturbing to note that practically every new engine has been conceived abroad. It was the Japanese Honda that sparked new U.S. interest in the stratified-charge engine. Today, Japan, because of its integrated, governmentally supported R&D effort, is also way ahead of the U.S. in the development of the electrical vehicle, which could be the future competitor to our automotive industry.

It should be recognized that the time for new engine penetration is very long. Figs. 8 and 9 show the history for commercialization [3]. The automatic transmission took 20 years, air-conditioning 17 years, and the disk brakes seven years from successful introduction to a 50 percent market penetration ("50 percent market penetration" corresponds to about 10 pecent of total cars on the road using the system.) The 50 percent penetration with the overhead valve engine took about six years.

In a recent EPA meeting, Ralph Cross, president of Cross Company, indicated that a changeover to a completely new engine would take 12.3 years based on present capacity of the transfer (automated manufacturing) machine industry. Another study [4] indicates that it would take about ten years (six years for preproduction and four years to full production). Thus, if technology readiness for the new engine system will only be available by 1980 and it takes about ten years for full production, the impact of the new power plants cannot occur until the early 1990s. With additional motivation and incentives, this period could possibly be shortened so that impact could be seen by the late 1980s.

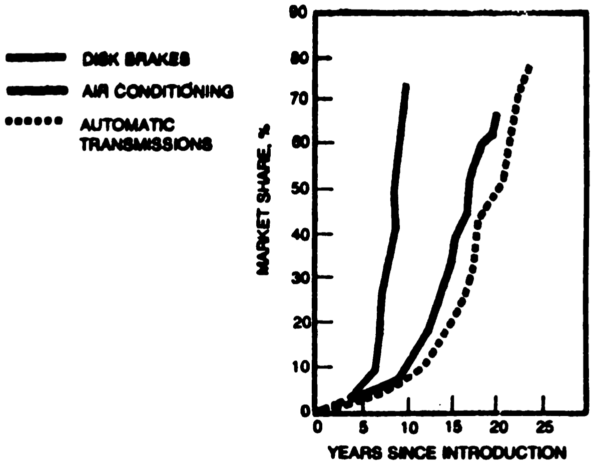

FIGURE 8.—Commercialization history—major automotive products

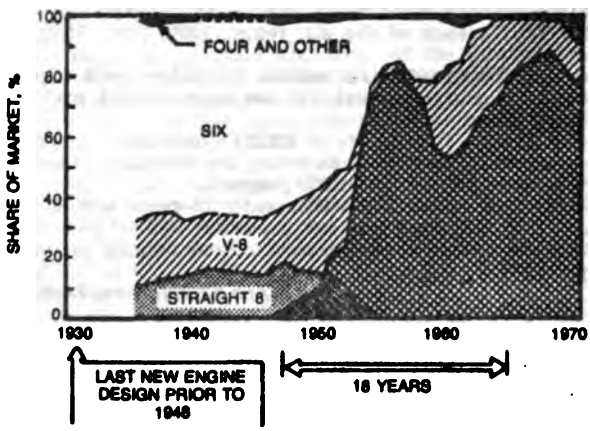

FIGURE 9.—Commercialization history—modern OHV engines

SUMMARY AND CONCLUSIONS

With the aid of some crystal ball gazing, the range of expected market penetration is shown in Fig. 10. In the near term, the stratified-charged engine looks potentially attractive, offering required low emissions without sacrifice in fuel economy. It does not add costly hang-on controls of questionable reliability, and it represents a relatively minor tooling change.

The catalytic converter will probably have a short history. Not only will it greatly increase cost and use materials that have to be imported, but also it is expected that its regular inspection and maintenance will bring its demise.

On a long-term basis, there are five candidates. It is expected that one of these will be the electric vehicle that will probably start making an impact in the late 1990s. The electrical vehicle may have its best application possibilities for urban travel, where the distances are relatively short and speeds are low. One can envision parking meters that also perform the recharging function. Hybrid (engine/electric) systems are also good candidates.

The other will be an engine probably with external combustion. The Stirling ine is the most likely candidate, although the diesel or the Warren engine show iderable promise at this time. It is too early to predict which of these has the

greatest potential. Therefore, additional studies and development are necessary. The Warren engine is the newest and has had very little development conducted on it. There is, of course, a chance that another power plant may emerge that has far greater potential than the ones cited. This is very unlikely, for it generally takes many years (five to ten) between concept and demonstration of feasibility and acceptance by technical and management community. However, if technology proceeds far enough so that ceramic turbines are capable of operating at high turbine inlet temperature and can be manufactured at relatively low cost, then the gas turbine [12] may become a major contender.

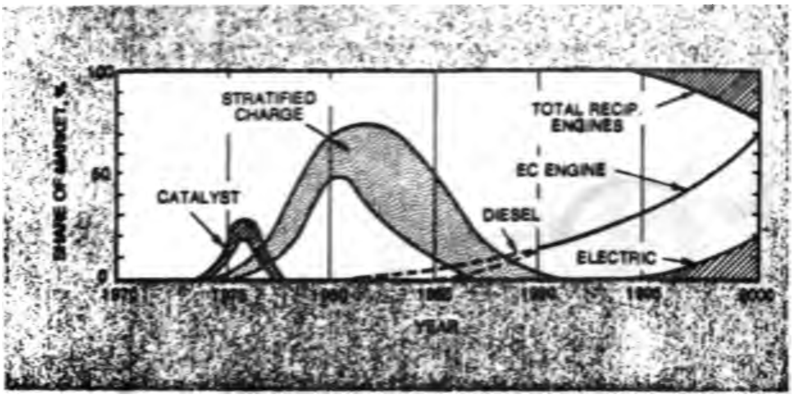

Figure 10.—Range of expected market penetration

The author does not believe that the Wankel, Rankine, or the gas turbine are likely to become automotive power plants with impact by the year 2000.

It is expected that the reciprocating piston engine will remain dominant at the turn of the century. However, it will probably change from internal to external combustion and will use various energy recovery systems.

Because of the many candidates and the various, often conflicting interactions, it is essential that a timely and effective process for screening be established. All the socioeconomic factors must be considered if one hopes to develop two viable automotive propulsion systems that will have impact by the year 2000.

Automobile manufacturers will undoubtedly continue to approach change with caution and will follow conservative introduction and commercialization strategies [3, 4, 13]. The socioeconomic requirements will play a much greater role in the selection of a power plant than they have ever played before.

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THE CHANGING AUTOMOTIVE ISSUES

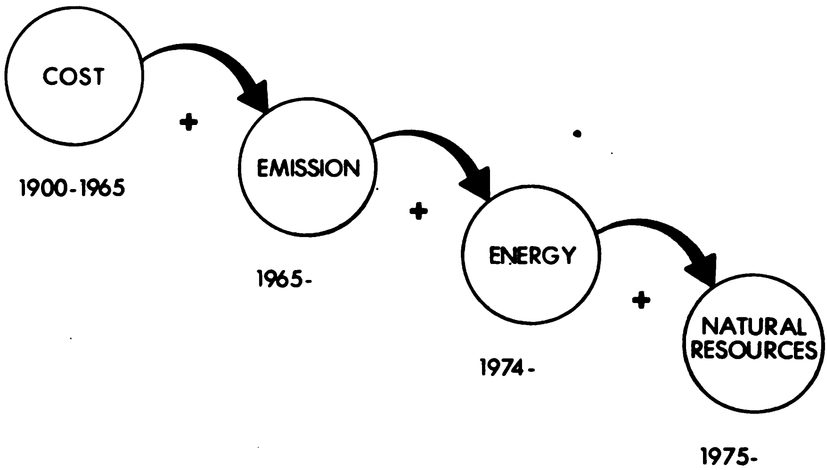

FIGURE 1

IMPACT ON NATURAL RESOURCES

Several materials which are currently among those in short supply are used in significant quantity in the automobile. Unchecked use will result in depletion before the end of this century. Further, these imports also represent a significant portion of U.S. mineral imports. This could impact directly on the balance of payments.

YEARS TO DEPLETION OF U.S. AUTO RESERVE - MATERIALS

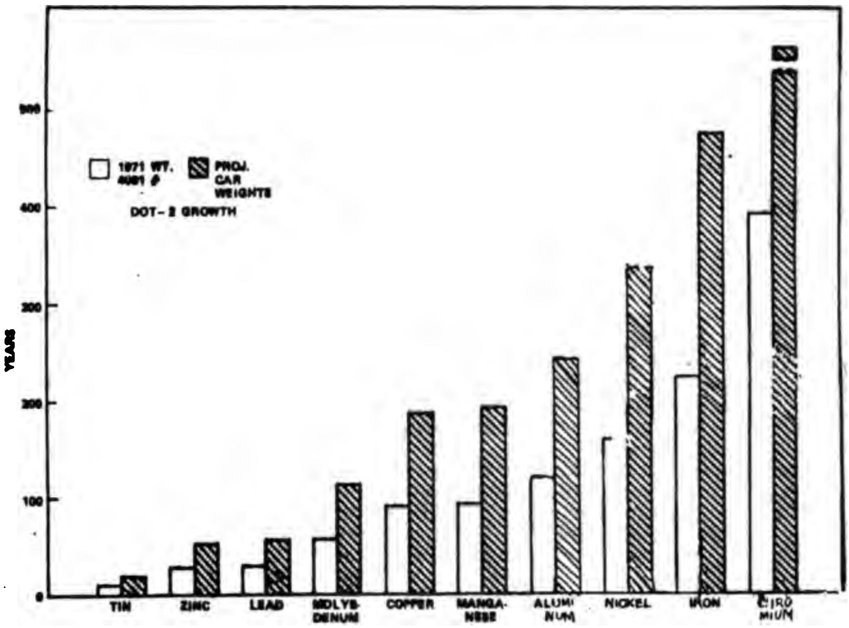

FIGURE 2

NATURAL RESOURCES - AUTO USE AND IMPORTS (1970)

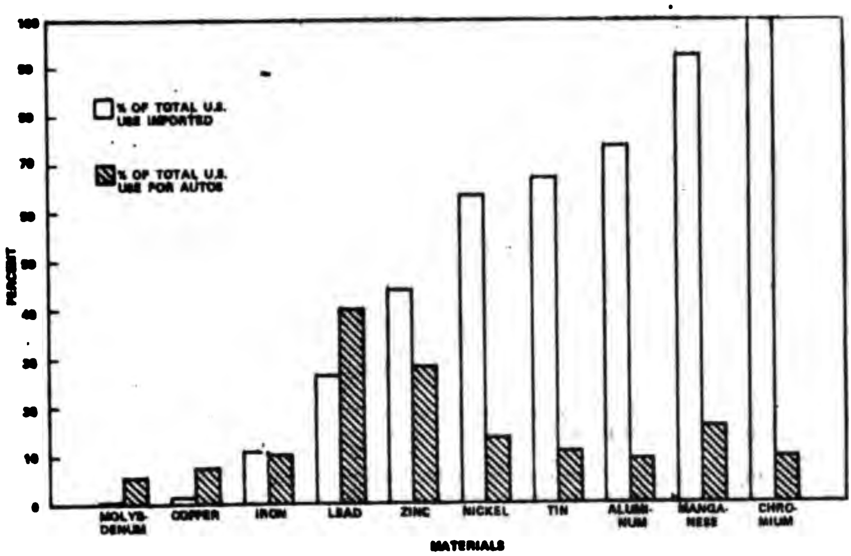

FIGURE 3

TABLE I.—AUTO METAL CONSUMPTION (DIRECT AND REPLACEMENT AFTER MARKET)

Metal	Pounds per auto		Millions of pounds		Percent used in U.S. autos (1950–70 average)
	Direct	After market	Total auto use 1973	Total U.S. use 1970	
Iron	3,500.0	496	38,633.0	324,000	10.0
Aluminum	65.0	17.7	799.5	7,835	9.0
Lead	28.0	99.3	1,230.7	2,710	40.0
Copper	30.0	7.9	366.4	4,370	7.3
Zinc	65.0	12.2	746.4	2,300	28.4
Nickel	4.5	.35	46.9	311	13.7
Chromium	8.0	.23	79.6	684	9.1
Molybdenum	.5		4.8	76	5.6
Manganese	12.0	3.5	149.9	2,296	5.7
Tin	2.0	.04	19.7	164	10.5

FORD MOTOR CO.,
Dearborn, Mich.

Hon. FRANK E. MOSS,
U.S. Senate, Committee on Commerce, Washington, D.C.

DEAR SENATOR MOSS: This is in response to your letter of September 19 to Mr. L. A. Iacocca regarding Ford Motor Company's views on pending electric vehicle research, development and demonstration legislation. We appreciate the opportunity to comment.

Attached you will find the Ford Motor Company statement and response to your questionnaire. We have also included a copy of a report entitled, "Should We Have a New Engine" prepared by Jet Propulsion Laboratory, California Institute of Technology. We hope the Ford response and the JPL report will be helpful to your Committee.

Sincerely yours,

FRED G. SECREST,
Executive Vice President—Operations Staffs.

Attachments.

FORD MOTOR COMPANY COMMENTS ON H.R. 8800/S. 1632 ELECTRIC VEHICLE LEGISLATION

Ford supports the accelerated research and development of electric vehicles. Electric vehicle commercialization, however, is severely limited by available battery technology, and we believe that research should be concentrated primarily on high-energy battery systems. The proposed demonstration program, however, may be premature because the technology does not exist for successful widespread use of electric vehicles. Since the demonstration program risks negative public reaction and diverts available funds from basic battery research, it may contribute to delaying the introduction of electric vehicles. Ford suggests, therefore, that electric vehicle legislation emphasize basic research and that demonstration projects be deferred until the high energy batteries currently in research become available. Hybrid technology, on the other hand, may progress enough to justify a demonstration project sooner, perhaps in three years.

Further, Ford considers Stirling and turbine engines as alternative technologies to electric and hybrid vehicles that offer at least equal potential for reducing air pollution and petroleum consumption. Consequently, they should receive at least as much funding as electric vehicle technology.

DISCUSSION

Electric vehicle operating characteristics currently limit them to specialized applications, such as low range urban cars, local delivery vehicles, buses and trains (as in some special applications in Germany and England), golf carts, lift trucks, etc. These limitations reflect the inadequacy of currently available batteries.[1]

The most widely used battery is the lead-acid battery, which has the advantages of low initial cost and (in some designs) relatively high power. Its main limitations are the limited energy per unit weight, short cycle life, particularly in

[1] Also see "Should We Have A New Engine?"—Volume II, chapter 8, Jet Propulsion Laboratory, California Institute of Technology, 1975.

high power configurations, and rapid deterioration in performance, both with age and with depth of discharge. Although progress has been made in various aspects of this battery, in general an improvement in one characteristic has been incompatible with improvements in other characteristics. For instance, although the Bell Telephone Laboratories have developed lead-acid batteries with significantly improved life, these improvements may be applicable only to the relatively lower power, high cost batteries used in telephone stand-by power. Significant improvements have been made in reducing the loss in performance with depth of discharge in the case of golf cart batteries, but these changes appear compatible only with batteries capable of too small a number of charge-discharge cycles (low cycle life). Similarly, batteries having very high power, at least when new and fully charged, have been demonstrated, but also in this case cycle life has been relatively short. The importance of the short cycle life is particularly serious in electric car applications, since the resulting need for frequent replacement negates any advantage accruing from the low initial cost.

Among the other batteries currently available, the most attractive in terms of performance characteristics is the nickel-cadmium battery, which combines the capability of high power with long cycle life. Unfortunately the initial cost of this battery is very high, both because of the high cost of the raw materials, particularly cadmium, and because of the very laborious manufacturing process required to impregnate the sintered plates which are needed to achieve simultaneously high power, long cycle life, and moderate energy density. In addition, the limited availability of cadmium precludes widespread application of this system. Other batteries currently in commercial production are totally impractical for electric cars, either because of excessive cost (as in the case of the silver-zinc battery), or of unsatisfactory performance (as in the case of the nickel-iron battery).

A wide variety of experimental batteries have been under development for some time which have various attributes, for instance, the nickel-zinc batteries and air-zinc batteries. All the evidence to date indicates that present technology cannot achieve truly long cycle life with these batteries. Moreover, the nickel-zinc batteries share the high manufacturing costs (although not the material costs) of the nickel-cadmium batteries, and the power capability of the air-zinc batteries is limited.

Although considerable attention has been given recently to the zinc-chlorine (or more accurately chlorine hydrate) battery, there appear to be intrinsic problems, as far as passenger car applications are concerned, due to use of a component (chlorine hydrate) which is unstable at normal ambient temperatures.

Therefore, Ford believes that the most promising batteries for electric vehicle application are the high temperature alkali metal batteries, such as the Ford sodium-sulfur battery, the Argonne lithium-metal sulfide batteries, and others. Since 1964 Ford has invested a significant amount of its own research funds on the sodium-sulfur battery. Currently this battery appears so promising that research on it is progressing at numerous laboratories, both in the United States and abroad. For the past two years, Ford's funds have been supplemented by support from the National Science Foundation. In this program, Ford is working jointly with two universities, the University of Utah and Rensselaer Polytechnic Institute, in order to solve the remaining research problems which center mainly on materials and manufacturability. Recently Ford has completed an agreement with the Energy Research and Development Administration aimed at the development of two types of batteries, a large, high-energy battery for load leveling of electric generating stations, and a smaller battery, combining high energy with high power for electric vehicles. Present plans call for construction of the first prototype vehicle battery in 1980. The program calls for construction of a vehicle which is specifically designed to match the characteristics of this prototype sodium-sulfur battery. As part of this program, a subcontract will be let to the University of Utah. If all goes well, commercial production of such sodium-sulfur batteries could begin as early as 1985. It is Ford's understanding that prototype lithium-metal sulfide batteries could also be available around 1980.

Until the projected developments required for these batteries are successfully completed, any all-battery electric car would be subject to the limitations inherent in the present lead-acid battery powered vehicles. Both the advantages and the limitations of these vehicles have been well established through extensive research and development programs (including Ford's own Electric Vehicle Program, which resulted in the demonstration of two such vehicles) and through extensive commercial production. Therefore, Ford believes that little additional benefit would be derived by the demonstration program that is provided in H.R.

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8800/S. 1632. Not only would such a demonstration have no foreseeable technological benefit, but it might also discourage a more productive future demonstration, such as may be appropriate approximately five years from now, when advanced systems such as sodium-sulfur and lithium-metal sulfide become available. There is also the additional risk of negative public perception mentioned in Question No. 3 of Senator Moss's letter.

The situation is somewhat different in the case of hybrid engine-electric vehicles, although, even in this case a demonstration of the type proposed in H.R. 8800/S. 1632 would be premature. Hybrid engine-electric vehicles combine the advantage of battery power with the flexibility in range of gasoline engines. Of greatest interest is the recent indication, which Ford has obtained both by system analysis and by limited engine dynamometer testing, that such hybrids, when properly configured may provide a significant improvement in fuel economy, while meeting an intermediate level of emission control. Ford has undertaken a program to demonstrate more conclusively this potential gain in fuel economy and to solve any problems which may be found with such hybrid systems. Even the application of this configuration may be limited, however, The initial promising results were obtained with nickel-cadmium batteries which, as mentioned above, are rather expensive. Although adequate power could be achieved with properly designed lead-acid batteries, the need for frequent replacement of these batteries may make them as unattractive economically as the nickel-cadmium batteries. Moreover, some questions remain as to the ability of the lead-acid batteries to deliver adequate power when aged.

Ford believes that hybrid engine electric-vehicles show significant promise and therefore believes that the system justifies a vigorous research and development effort. However, as indicated above, a demonstration involving the manufacture of large numbers of such vehicles would be premature.

If a demonstration program is conducted, the timing between purchase phases appears to be very tight. Ford suggests that more time be allowed between the purchases to permit problem identification, redesign to correct problems, and implementation of these changes into production. Ford is also concerned that the demonstration program on such a large scale is, in reality, a commercial project which should be left to the private sector and not conducted by government.

Other potential promising areas for research and development include flywheel energy storage systems, low cost motors and controllers, regenerative braking, safety features, particularly for electric vehicles, and more efficient accessories including heaters, defrosters, and air conditioning systems for electric vehicles.

Except for specialized applications, it is not clear that electric vehicles will necessarily save any significant net amount of energy. This is due mainly to the losses in electric generation, transmission, battery charging and generation of vehicle power. In general, the main benefit would be to replace the use of gasoline with that of other fuels. Unless electrical energy becomes widely available from non-petroleum sources, the savings in either energy or petroleum may be minimal. Ford suggests, therefore, that any such demonstration project be concentrated in localities where electrical energy is derived largely from sources other than petroleum. Ford also suggests that Section 9(b) (of both H.R. 8800 and S. 1632) be changed so that the administrator's continuing assessment include an analysis of the long-range energy and petroleum effects of electrifying urban traffic.

On the positive side, it is true that emissions might be more easily controlled locally. The use of electric vehicles could increase system efficiency by charging at off-peak period. Air quality in urban areas could be improved if generators are located in rural areas, however, generators would require NO_x, SO_2 and particulate controls.

Other approaches to reduction in petroleum derived fuel consumption should be pursued. For instance, the industry has demonstrated that significant improvements in fuel economy can be achieved with conventional engines. Further improvements will require significant vehicle weight reduction. For this purpose Government support of research and development on light-weight materials for automotive use would be of great value.

Ford has in place major programs for the development of Stirling and gas turbine engines. Both of these show the potential of major fuel economy improvements and low emissions. Continued and hopefully increased Government support of this research and development is highly desirable and would undoubtedly hasten the introduction date for these systems (see referenced JPL study).

One element of this legislation that had drawn some favorable comment is that it promotes small company participation in electric vehicle technology. If this can be achieved without adversely affecting the research objectives (which is far from certain), there would seem to be no reason why similar safeguards could not be applied to a program geared primarily to battery research.

In summary, Ford supports efforts to accelerate the introduction of electric vehicles in a manner that significantly reduces petroleum consumption and improves urban air quality. However, the demonstration program appears to be premature, since technology to support it will probably not be available. Research and development should be accelerated so that improved batteries, hybrid engine-electric vehicles, Stirling engines and turbine engines will be available at an early date for subsequent demonstration and ultimate production and use.

RESPONSES TO QUESTIONS CONCERNING S. 1632/H.R. 8800

Answer No. 1. Change Section 9 so that Administrator's assessment includes the long-range impact of urban traffic electrification on energy and petroleum consumption.

Defer demonstration program until significantly improved batteries become available.

Revise the legislation to place primary emphasis on battery research.

Answer No. 2. Ford sees no significant benefits from the demonstration program as proposed.

Answer No. 3. There is a risk of negative public perception. Ford can suggest no restructuring that will reduce this risk if the demonstration program is implemented on the proposed timetable.

Answer No. 4. One year probably is adequate for purchase but not for evaluation of 200 to 300 vehicles.

Answer No. 5. The time schedules for purchases number 2 and 3 appear too tight to permit evaluation, problem identification, redesign and implementation of redesigned components in production. In addition, Ford doubts that battery technology will have progressed sufficiently to provide significant improvements during the entire demonstration program.

Answer No. 6. All-battery electric vehicles will probably not change very much during this time period. Hybrid research will probably progress enough to establish potential gains in fuel economy. However, during this period, the economics of hybrids will probably be attractive only under highly specialized conditions.

Government supported basic battery research is probably the most effective government policy for contributing toward commercialization of electric and hybrid vehicles.

Answer No. 7. In addition to battery research, other Federal R&D efforts might profitably focus on flywheel energy storage systems, low cost motor and controller systems, regenerative braking, safety, accessory drive systems, and vehicle weight reductions.

On a national basis, a total of $50 million seems appropriate for research and development (but not demonstration) on batteries, other components and hybrids.

Answer No. 8. Stirling and turbine engines appear to offer more promise of reducing petroleum consumption and automotive emissions than electric vehicles and possibly within a shorter time period (see "Should We Have a New Engine?", Jet Propulsion Laboratory, California Institute of Technology, 1975).

Although electric and hybrid vehicles should be given substantial research efforts, Stirling and turbines engines should be given greater research efforts.

Answer No. 9. Ford has no comment at this time.

Answer No. 10. Ford has no comment at this time.

Answer No. 11. Chapter 8, Volume II of the previously mentioned 1975 JPL study "Should We Have A New Engine?" provides a summary of electric vehicle performance characteristics.

Ford does not anticipate major improvements in lead-acid battery technology during the next 5–10 years that will improve electric vehicles.

Answer No. 12. High temperature alkali metal batteries, such as sodium-sulfur, show the most potential for future use in electric vehicles. Although timetables are difficult to forecast, it may be possible to have a prototype battery in the early 1980's and production by the mid 1980's. The intermediate performance batteries (i.e. zinc batteries) do not appear to offer enough improvement.

The performance characteristics of the high temperature alkali metal batteries may allow power equal to conventional cars and a range possibly in excess of 100 miles. The costs of these batteries have not yet been determined.

Answer No. 13. Ford has no comment at this time.

Answer No. 14. Not enough is known about the safety implications of electric vehicles to comment at this time, but we do not anticipate major problems. This is an area that requires research.

Answer No. 15. Ford has no comment at this time.

Answer No. 16. Ford has no comment at this time.

MASSACHUSETTS INSTITUTE OF TECHNOLOGY,
Cambridge, Mass., October 1, 1975.

Senator FRANK E. MOSS,
Subcommittee for Consumers, Committee on Commerce, U.S. Senate, Washington, D.C.

DEAR SENATOR MOSS: Within the M.I.T. Energy Laboratory, we are now completing a study of the federal role in automotive propulsion research and development. As this study includes consideration of electric vehicles, we welcome the opportunity to comment on S. 1632 and H.R. 8800 and the list of questions which you sent us. The final report in our project, which discusses the electric vehicle option in some detail, will be available later this fall and copies will be provided for your consideration. In the interim, we submit the following material in response to your request.

In brief, while sympathetic to the objectives of the proposed legislation, we believe that the bills, as drafted, could easily be counter-productive, damaging rather than enhancing the prospects for an electric vehicle industry capable of making a significant national contribution before the end of this century.

We recognize that this view is considerably more pessimistic than those presented by the great majority of witnesses at the House hearings. In explaining this divergence of view (and specifically in response to your Question 3) we would draw special attention to the widespread tendency to assume that the commonly quoted ranges of existing electric vehicles in fact represent reasonable approximations of practical range, as it is likely to be perceived by the driver. On this basis, it is frequently claimed that the ranges of electric cars with current technology batteries are very adequate for typical urban driving. But such comparisons are quite drastically misleading.

The problem, in part, is that the generally used basis for estimating electric vehicle range (the Society of Automotive Engineers (SAE) Metropolitant Driving Cycle) is substantially less demanding than actual typical driving conditions. Also, such calculations of range are usually based on new battery performance. While the total energy per mile required for the SAE cycle seems quite reasonable, the peak rate at which energy must be provided (the power demand) is substantially below what an urban vehicle would normally encounter. But the total energy that can be delivered by a battery (and thus the range it can provide in a vehicle) is strongly influenced by the peak power demands experienced during acceleration and hill climbing.

Some effort has been made (on paper) to calibrate performance on the SAE cycle with performance on the more realistic EPA urban driving cycle used for testing conventional cars. But until these calculations have been verified by on-the-road performance tests, one must be concerned that average range in actual driving (even with a new battery) will fall significantly short of the nominal range based on the SAE cycle.

Even more important, though, it is assured range over the life of the battery, not average range with a new battery, that is likely to be critical for the individual driver. Actual range will vary sharply with the age of the battery, the driving habits of the individual driver, weather and traffic conditions, and so on. Even in the most favorable areas of the country, with few hills and mild climates, is doubtful that the assured range of electric cars could reach 50% of the range derived with the SAE cycle. In less favorable situations, assured range may not exceed 20% of the SAE derived range. When these very real effects are taken into account, in our judgment it becomes extremely doubtful that many drivers would find a near future electric car a satisfactory substitute for a conventional second car, even if one assumes that subsidies are provided to make the costs comparable.

There does exist today a market—but a very limited market—for electric passenger cars even with current technology. [illegible] market today for [illegible] ... a [illegible] market, where [illegible] ... We are concerned that the demonstration program as defined in the draft legislation may amount to little more than an effort to expand this limited [illegible] inherently self-limiting market, [illegible] will amount to very [illegible] to a minute [illegible] national significance [illegible] number of electric vehicle users.

We feel that such a program is considerably more likely to produce disillusionment with the electric vehicle option than to "demonstrate commercial feasibility" as intended. It is also likely to have the unfortunate consequence of focussing the federal funds available for electric vehicle and battery research on near term efforts with severely limited potential, rather than on more realistically planned efforts to create a viable electric vehicle option for the nation over the longer run.

In the light of these points, we believe the most important change needed is the legislation—and we recognize that this is likely to be resisted by most supporters of the legislation as a drastic change indeed—is to [illegible] electric vehicle demonstration on fleet operations, such as urban delivery vehicles, buses, or postal vehicles for use within restricted zones, rather than on private passenger vehicles. We believe that the case is very strong that battery technology adequate to power a reasonably competitive urban passenger car cannot be available on a time schedule approaching those set by the draft legislation. Indeed, even in the much more favorable context of fleet applications the opportunities for advantageous demonstrations may be quite limited for the next few years.

Sincerely,

John B. Heywood,
Associate Professor of Mechanical Engineering.
Lawrence H. Linden,
Research Associate, Energy Laboratory.
Howard Margolis,
Research Fellow, Center for International Studies.

Consumers Union, Inc.,
Mount Vernon, N.Y., October 2, 1975.

Senator Frank E. Moss,
Chairman, Subcommittee for Consumers, U.S. Senate, Committee on Commerce,
Washington, D.C.

Dear Senator Moss: This is in response to your letter of September 19, 1975 addressed to Rhoda Karpatkin. We have annexed our answers to the specific questions raised concerning S. 1632 and H.R. 8800.

The October issue of Consumer Reports magazine was especially timely for we tested two electric vehicles that are now widely available in the USA. As it turned out we found these two vehicles to be substandard in many ways and we rated them Not Acceptable. These ratings, of course, apply only to the tested vehicles, not to electric cars in general. Our report simply shows that the two products tested did not measure up to what we consider to be state-of-the-art standards. Had they both been powered by internal combustion engines, and had they performed as they did, they both would still have been rated Not Acceptable.

Our report calls for the continuation of experiments with electric cars. It points out that the problems we uncovered in the two samples are solvable. And it comments positively on the Energy Research and Development Administration project to explore further the feasibility of electric vehicles.

We agree that the electric vehicle has an important role to play in the transportation scheme of the 1980's. It exchanges mobile source pollution for stationary source pollution—a most important factor for our cities. But that benefit is not enough. An electric vehicle must also be safe to ride in and drive, it must competitive in operating costs with economical heat-engined cars in the face of rapidly rising electricity costs, and it must have sufficient range and performance to be truly practical. The domestic auto industry has been in no hurry to develop electric vehicle competition for its conventionally-powered cars. For that reason, if for no other, Federal financing of electric research and development is surely

needed. We concur with electric vehicle experts who believe that the battery is the weak link in the future development plans for electric vehicles. The greatest pay-off will probably come from that portion of the pending legislation which would fund battery research and development.

We are less enthusiastic about that part of the legislation relating to demonstration projects. We point out some of the pitfalls in our answers to the questions posed by the Committee. The basic question is whether the Government should fund the building of many hundreds (or even thousands) of automobiles when the primary problem area is in the propulsion system itself. Consider the Experimental Safety Vehicle project: only a few were built at great expense and very little of that project has filtered down to production automobiles. The scope of this legislation is much larger and the logistics of dealing with the many manufacturers and inventors will be much more difficult.

Sincerely,

ROBERT D. KNOLL, *Head, Auto Test Division.*

Enclosure.

QUESTIONS CONCERNING S. 1632 AND H.R. 8800

Question No. 1. What changes or additions would you make to S. 1632 or H.R. 8800?

Suggested changes or additions to the bills will be explained in the subsequent answers.

Question No. 2. What specific benefits do you see arising from such a demonstration program?

The major benefit, with the timetable proposed, would be an acceleration in the development of electric and hybrid vehicles. It is important, however, that the "initial performance standards and criteria for purchase number 2" be challenging enough technically so that genuine advances are made in battery technology. It is also important that those standards stress occupant safety.

Question No. 3. Some electric vehicle proponents raise the concern that "premature" demonstration might lead to a negative public perception of electric vehicle potential due to alleged limited cost and performance characteristics of existing electric vehicles. Do you agree or disagree that this danger exists? If you agree, how might the demonstration program be restructured to avoid this problem? If you disagree, please indicate why.

We agree that such a danger exists. Indeed, our report on two commercially available electric cars in the October issue of Consumer Reports magazine could foster just such a public perception. The problem, as attested to by our report, is that the electric vehicles now sold widely in the USA are not "state of the art" so far as their body and chassis are concerned, but more closely resemble licenseable golf carts. We have seen reports of, but have not tested, other low-production electric vehicles that purport to be much closer to conventional motor cars. Some are "conversions" of passenger cars. In order to avoid this problem, the demonstration project cars should be limited to vehicles which, in their original form, have been certified as complying with existing Federal motor vehicle safety standards. In this way, although the safety of the electric cars would not be assured, at least it would be starting from some defined point. Electric, battery-powered vehicles have their own unique problems as far as crashworthiness is concerned. Thus it is important that they start off with a proven crashworthy chassis.

Question No. 4. Is one year a sufficient time in which to purchase and evaluate a baseline electric vehicle fleet of 200 to 300 vehicles, and develop performance criteria for purchase number 2? If not, what time frames would you suggest?

On the basis of our testing experience we judge one year as an extremely optimistic time for letting purchase contracts, and designing and performing tests on a fleet of 200 to 300 vehicles. After all, the electric vehicle industry is in its infancy and many manufacturers of electric cars cannot be considered to be "in production." It would take considerable time just to weed out those who do not have a viable product but merely wanted to cash in on the possibility of having the Government as a customer. The demonstration project also must cover a certain time span in order to evaluate the reliability of the vehicles and their suitability under a variety of climatic conditions. Since the design of the performance criteria for purchase number 2 is so very critical, sufficient time must be allowed to do the job properly. We would suggest that 2 years would be more feasible.

Question No. 5. Are the time schedules for purchase numbers 2 and 3 appro-e? Please explain.

Given that the demonstration project could be done within 2 years and that the performance criteria for purchase number 2 could be established in several more months, we think that the timetable for purchase number 3 would be very indefinite. There is even a doubt whether purchase number 3 would be necessary at all. If the guidelines for purchase number 2 are sufficiently challenging, and if the electric vehicle industry has done its homework, then why would it be necessary for the Government to subsidize the industry by buying all its products? If the projects go ahead as planned, and if the vehicles in purchase number 2 are viable and useful vehicles, then the resources of the Government should be directed to the design and development of components (in areas such as batteries and fuel cells) rather than in whole-car projects. After all, industry does know how to make a useable motor car. What it does not know how to do is power an electric car economically and reliably.

Question No. 6. What, in your opinion, will be the state-of-the-art in electric and hybrid vehicles within 42 months of enactment of H.R. 8800 assuming enactment during 1975? What government policies would contribute most to commercialization of electric and hybrid vehicles?

Enactment of H.R. 8800 would, in our opinion cause a scramble within the electric vehicle industry to see who could qualify to sell the Government the most vehicles. The state-of-the-art will only be improved if the demonstration projects use viable electric cars and if the guidelines for purchase number 2 are tough enough to encourage improvements in the state-of-the-art of battery design.

We question whether it should be the Government's policy to contribute most to "commercialization" of electric and hybrid vehicles. Rather the Government should contribute to the funding of the necessary research toward better batteries, the weakest link in the future development of electric vehicles.

Battery research is clearly the single most important component in the future development and acceptance of electric vehicles. In order to move them out of the novelty class into a range of performance where they can take their rightful place in the transportation picture, a major step must be taken to find an alternative electrical power source other than the lead-acid battery. We agree with the summary findings of the JPL Report "Should We Have a New Engine?" wherein they conclude that a major breakthrough in battery technology is required to make electric vehicles competitive with heat-engined vehicles and, further, that near-term R and D funding should be primarily directed toward battery research.

Question No. 7. In addition to battery research, where should a fedral R&D program on electric and hybrid vehicles focus its efforts? How much funding should be provided for battery research and these other efforts during the next 5 years?

Refer to Question No. 6.

Question No. 8. Are there other vehicle technologies that offer comparable reduction in petroleum consumption and reduction of environmental impact to that of electric and hybrid vehicles? If so, is the special emphasis given to electric and hybrid vehicles in S. 1632 and H.R. 8800 justified? Please explain.

We have no direct experience with other vehicle technologies and suggest that the JPL Report be carefully reviewed.

Question No. 9. How can an adequate manufacturing base and adequate competition be assured in electric vehicle production? Do S. 1632 and H.R. 8800 adequately address these needs? What changes or new provisions might be useful in this regard, if any?

We do not have the information necessary for a response.

Question No. 10. What infrastructure (for example, public or private recharging station, maintenance and service facilities, etc.) must be developed to support the demonstration program called for in S. 1632 and H.R. 8800? What problems might be anticipated in establishing such an infrastructure?

Since the electric vehicle industry is fragmented at the present time, a danger exists that small manufacturers could set themselves up to make a certain number of vehicles, sell them to the Government, and then go out of business. In this way they would reap the short-term profits and would not have to build into their corporate structures the sales, service and parts organizations so vital to the support of a motor vehicle from a consumer point of view.

Question No. 11. What are the performance characteristics of current technology electric vehicles? What improvements in lead-acid battery technology do you foresee in the next 5 and 10 year periods? What are the implications of these

improvements for the performance characteristics and purchase and life cycle costs of electric vehicles?

For information on the performance of two currently available electric vehicles we refer you to the October 1975 issue of Consumer Reports and we have annexed a copy of that report. We do not foresee dramatic improvements in lead-acid batteries in the next few years. Lead-acid batteries have been in use in electric vehicles for 75 years with steady improvement but no breakthroughs. The major implication of improved battery technology will be much improved performance characteristics but at higher life cycle cost.

Question No. 12. In your opinion, what other batteries show promise of future use in electric vehicles, and on what time tables? What performance characteristics and costs will be associated with the use of these other batteries?

We do not have the information necessary for a response.

Question No. 13. What problems or constraints might arise in large scale manufacture of electric cars with respect to production equipment and manpower skills? What problems might be anticipated by electric vehicle manufacturers in the areas of materials or capital availability?

We would expect no problems in the large scale manufacture of electric vehicles with respect to production equipment or manpower skills. The major problem with large scale manufacture will be the raw materials necessary, some of them very expensive and in short supply—copper, for example. We do not have the information necessary to respond to the question about capital availability.

Question No. 14. Please state your views on the current and future applicability of safety standards and regulations to electric and hybrid vehicles.

The development of alternative, cleaner power sources must not be allowed to inhibit the gradual progress that has been made in reducing the death and injury rate on the nation's highways. Every effort should be made to insure that the electric and hybrid vehicles involved in the demonstration project be as safe and crashworthy as possible. To this end the NHTSA should be instructed to examine very closely each application for exemption from any standard. State-of-the-art handling and braking must also be required, since active safety must be stressed as well as passive safety. Part of any demonstration project, and an integral part of the performance criteria for purchase number 2, must be full-scale crash tests.

Question No. 15. What steps might the Federal government take to facilitate introduction of demonstration electric and hybrid vehicles into state and local government fleets?

We do not have the information necessary to respond.

Question No. 16. What institutional impediments do you see to the widespread introduction of electric vehicles?

The question is not clear to us.

Two Electric Cars

Electric cars have been marketed without much success since before the turn of the century. In recent years, concern over air pollution caused by the internal combustion engine and the rising cost of gasoline have revived interest in electric cars. CU therefore decided to test the only two electric cars being sold in any volume in this country: the *CitiCar SV-48* and the *Elcar 2000*. We found major safety and operating problems.

The *CitiCar*, made by Sebring-Vanguard, Inc., of Sebring, Fla., costs $2946 delivered to our Auto Test Center in Connecticut. The *Elcar*, an Italian import distributed in the U.S. by Elcar Corp., Elkart, Ind., cost $3475 delivered.

Conventional passenger cars must conform to certain Federal safety standards. But to spur the development of low-emission vehicles, the Government has granted temporary exemptions from some of those standards to manufacturers of electric cars—with unfortunate results.

Conventional cars must provide life-saving protection to occupants in a 30-mph barrier crash, a 30-mph rollover, and a 20-mph side impact from another car. We believe any such crash would imperil the lives of persons inside these tiny, fragile, plastic-bodied vehicles. A rollover or a severe crash holds the further threat of sulfuric acid pouring from ruptured batteries. (The batteries are under the padded-plywood seat cushion in the *CitiCar* and under the plywood floor in the *Elcar*—both within the passenger compartments.)

There are other obvious hazards no longer tolerated in conventional automobiles. Adjusting the safety belts is discouragingly complicated. Yet the windshield frame in the *CitiCar* is just a few inches in front of the forehead of all

occupants, making the use of shoulder belts especially important. The *Elcar's* safety belts are not much better.

The *CitiCar* has no steering-wheel lock, and the doors cannot be locked. The hinges and latches looked so flimsy that we tied the doors shut before performing any emergency-handling tests. (The *Elcar's* door hardware also looked flimsy, but at least the doors and steering column had locks.)

In both cars, very wide front and rear roof pillars interfere with the driver's view, as do single wipers in the center of the windshields. The spare tires are free to roll around behind the seats and could cause injury in an accident.

The *CitiCar* has a welded-aluminum "roll cage" intended to keep the plastic body from collapsing during a collision; we doubt that it provides as much protection as a well-designed steel body. But steel is heavy, of course, and would make the car even slower than it already is.

The *Elcar* has yet another mark against it: Its suspension is too flimsy to cope with even the low level of performance of which the vehicle is capable. During hard braking tests from 30 mph, the front suspension collapsed, putting an emphatic end to our testing of the *Elcar*.

The manufacturer of the *CitiCar* specifically warns owners that the vehicle should be used only on roads where the speed limit does not exceed 30 mph. The *Elcar* is promoted simply as "perfect on-street transportation for in-town use." But we believe it would be foolhardy to drive either car on any public road. Neither provides anything close to adequate crash protection; and neither handles or accelerates well enough to give us confidence that they're capable of getting out of a tight spot.

CU hopes experiments with electric cars continue. A practical, safe, economical electric car might be just right as a second car limited to short commutes and shopping trips. But neither the *CitiCar* nor the *Elcar* is practical, safe, or economical. We rate both of them Not Acceptable.

On the two pages that follow we report on our tests of these two cars in more detail. However, the results are presented primarily to satisfy the understandable curiosity about electric cars, not as the basis for a rational purchase.

The *CitiCar* is a two-seater, 95 inches long and 55 inches wide. Ours weighs 1308 pounds, including a propane heater ($90) for the occupants and a spare tire and wheel ($36). The *Elcar* also is a two-seater, but it is only 94 inches long and 53 inches wide. Ours weighs 1145 pounds.

The *CitiCar's* 3.5-horsepower motor is powered by eight six-volt batteries similar to those used in golf carts. The accelerator pedal actuates a three-way speed control. Step down one notch and a resistor allows a smooth take-off by limiting the amount of voltage to the motor. Depressing the accelerator pedal further feeds 24 volts to the motor. Stepping down on the accelerator pedal all the way supplies 48 volts to the motor for maximum speed. A built-in charger (photo, below left) plugs into a household outlet to recharge the batteries.

The *Elcar* has a smaller motor rated at 2.7 hp and powered by eight 12-volt batteries. Its electrical controls are more complicated than the *CitiCar's*. A rotary actuator on a column (much like those in old-time trolley cars; see photo, below right) provides three positions: 24 volts, 36 volts, and 48 volts. There's also an accelerator pedal that provides two speeds in each selector position, for a total of six forward speeds. For maximum cruising speed, one flicks a "booster power" toggle switch when in the third selector position. A charger is included in the price of the *Elcar*, but it is not mounted on board. We mounted ours in the rear compartment.

IS ELECTRICITY A CHEAP FUEL?

To test the batteries' endurance, we ran each car repeatedly around a substantially level one-mile course, permitting the car to rest for one minute after each mile and for 15 minutes every half hour. That cycle was designed to simulate an urban drive with several shopping stops.

With the temperature at about 80° F., the *CitiCar* was able to run 33.8 miles on that cycle and then required 14 kilowatt hours (kwh) to recharge fully. In the New York City area, where a kwh costs about nine cents, the energy cost per mile would be 3.7 cents; in some areas, it might be as low as 1.2 cents. By comparison, if the *Honda Civic CVCC* (see page 625) delivered its city mileage of 21 mpg in that same cycle, fuel cost per mile would be about three cents, assuming gasoline at 60 cents a gallon.

The *CitiCar* does not need the oil changes and tune-ups that the *Honda* and other gasoline-burning cars require. However, the *CitiCar* will require a new

set of batteries after 400 to 600 recharges, or about 11,000 to 16,000 miles. The batteries would cost about $320, plus labor.

In the same urban shopping cycle, the *Elcar* was able to run 33.2 miles and required 12.8 kwh to recharge the batteries. That figures out to 3.5 cents per mile where electricity costs nine cents per kwh. The *Elcar* would also need new batteries every 11,000 to 16,000 miles. Cost: $250 to $300, plus labor.

Thus, where electricity is relatively expensive, neither electric car would be cheaper to run than the most economical of standard subcompacts.

A BATTERY OF WOES

How well (or, more precisely, how poorly) these cars performance depends a great deal on the outside temperature. For example, during the summer our *CitiCar's* useful range without rest periods was about 20 miles; but when the temperature fell to 40° F., the batteries needed to be recharged after less than 10 miles. A full charge usually took more than eight hours.

Other factors affect range. Running at top speed (32.5 mph for the *CitiCar*, 30 mph for the *Elcar*) drains batteries relatively quickly. So does driving in hilly country. Because the headlights of both the *CitiCar* and the *Elcar* dimmed to virtual uselessness by the time half the charge had been consumed, you couldn't (or shouldn't) drive these cars more than about 15 miles after dark.

Acceleration was slow. The *CitiCar* required 17.7 seconds to reach 30 mph. The *Elcar* couldn't quite get up to 30 mph on our test track; it took an excruciating 27.5 seconds to reach 29.5 mph, dangerously slow acceleration even for city streets. Hill-climbing ability of both cars was poor.

The handling of these vehicles hardly inspired driver confidence. During sharp steering maneuvers, the *CitiCar* at first plowed straight ahead; then it would suddenly swing its rear end rapidly to and fro. Bumps caused the car to hop sideways, off course; that characteristic was aggravated by the *CitiCar's* violent ride motions, which caused the driver to turn the steering wheel unintentionally.

The breakdown of the *Elcar's* front suspension prevented us from performing formal handling tests on that vehicle. But the *Elcar* felt tippy and directionally unstable during normal driving. As in the *CitiCar*, the steering was very quick and unpredictable.

Our braking tests went no better. The *CitiCar's* nonpower brakes (discs in front, drums in rear) required high pedal effort—about 120 pounds to lock the wheels. From 30 mph, the *CitiCar* stopped in 51 feet with no wheels locked and in 43 feet with all wheels locked and the tires sliding. Directional stability was not good; the car swerved and pulled, generally coming to a stop at about a 45-degree angle from the direction of travel.

The *Elcar*, with its nonpower all-drum brakes, weaved and leaned sharply when braking from 30 mph. During one hard stop, it almost rolled over. When we tried to stop shorter than about 70 feet, the rear axle hopped. Our shortest stop, 47 feet, involved a sharp veer to the left.

INCONVENIENCE, DISCOMFORT

One would imagine that small electric cars would be most useful for short shopping trips in urban and suburban areas. But even here, the *CitiCar* and the *Elcar* fell down. Neither vehicle has a rear opening, so one must fold the seatback forward and load shoping bags through the narrow door openings. In the *CitiCar*, a horizontal bar that supports the seatback obstructs access to the cargo area. And in the *Elcar*, the seatback doesn't stay folded without a prop. Neither car can hold more than a few small packages.

The seats in both cars were too firm and gave inadequate support. In the *Elcar*, the seat cushions can be adjusted both forward and backward. When tall drivers adjusted the *Elcar's* seat all the way back, they found the leg room adequate—but then the steering wheel was too far away. The small brake pedal was too far to the right. Protruding wheel housing limited foot room for the driver and passenger. Entry and exit were difficult.

The seat in the *CitiCar* allows no adjustment. You either fit comfortably or you don't (most CU drivers didn't). Leg room was very tight. The optional propane heater encroached on the passenger's foot room, the steering wheel was too far to the right, and the brake and accelerator pedals were awkwardly high and close. Entry and exit were difficult. The inside mirror not only threatened one's head during entry, but it was distractingly close to the drivers's eye.

The *Elcar's* door windows slide horizontally rather than rolling down. They gave adequate protection from the elements. The *CitiCar*, however, has only draftly, flimsy side curtains like those of many early British sports cars.

One might expect an electric car to be quiet. The *CitiCar* and the *Elcar* are quiet only when stopped. At 30 mph on a coarse road, our sound measurements showed the *CitiCar* to be the noisiest vehicle we have tested this year—about as noisy as the *Honda Civic CVCC* was at 60 mph.

The failure of the *Elcar's* front suspension prevented us from recording that vehicle's noise levels, but the *Elcar* seemed to us at least as noisy inside as the *CitiCar*.

The *CitiCar* felt as if it had no springs at all. The car rode uncomfortably on every type of road surface. The *Elcar's* independent suspension gave a somewhat less painful ride. Even so, the car bobbed busily on all but the smoothest roads.

MISCELLANEOUS COMPLAINTS

The *Elcar* has no fresh-air ventilation system. Even with the windows open, the care was hot and stuffy in the summer. The *Elcar* also lacks a heater or defroster, perhaps a concession to the fact that cold weather makes the car's range impractically short anyway. In its petition for exemption from Federal safety standards, the manufacturer of the *Elcar* claimed that the sliding windows would alleviate fogging—but that proved true only when the car was moving.

What fresh air entered the *CitiCar* came in mainly past the ill-fitting side curtains. In cold weather, the constant draft was unpleasant. A switch labeled "defroster" is a dummy. According to the owner's manual, it's "not funtional on most models." The optional propane heater was hard to light and modulate. And it quickly fogged all the windows (one of the products of the heater's combustion is water vapor).

In our opinion, most of the many serious breakdowns that afflicted our *Elcar* were design flaws. Our *Elcar* sat in the shop awaiting parts or undergoing repair for a total of 74 days—more than half the time we owned it—until its virtual demise. The main power fuses for the high speed ranges blew repeatedly for no apparent reason during the 370 miles we drove the car. We had to order replacement fuses from the distributor. Each time a fuse blew, we limped home in low speed range and waited for a new fuse to arrive. Recently, the distributor shipped us a circuit breaker to replace the fuse box—a much-needed improvement scheduled for future production.

At just over 100 miles, a short circuit produced a brilliant flash of light from the headlights, and the wiper went berserk, wiping at a frantic pace. According to the distributor, such short circuits occur occasionally, because of inadequate accessory wiring design. We received a wiring kit to correct the defect.

Loose connections at the main power fuse box resulted in a loud clicking noise from the turn-signal flasher when we tried to charge the batteries. That flasher, incidentally, was another weak component; it had to be replaced twice.

At 210 miles, the differential gears disintegrated during normal driving and the car ground to a halt. The replacement gears lasted another 160 miles before crumbling during our braking tests.

The horn failed when grease from the steering column fouled the switch contacts. A moderate tug on the parking-brake handle caused the parking-brake assembly to break in two. The wiper arm, retained only by a set screw, slipped on its drive shaft. The final blow was the suspension failure mentioned earlier.

Our *CitiCar* never left us completely stranded during the time we owned it, although it gave us some anxious moments, as the diary on the facing page indicates. The *CitiCar* suffered from fewer defects than the *Elcar*, and most of those were caused by sloppy manufacture rather than by design flaws. However, four defects were serious. After about 125 miles, the warning light for motor overheating went on even though the motor was only normally warm. At 370 miles, a loose wiring connection caused the voltmeter to flicker and the horn to fail. Most serious, the steering wheel retaining nut was very loose, and all the spring fasteners in the front and rear suspension were loose; had those items gone unnoticed, they could have caused an accident.

THE FUTURE OF ELECTRIC CARS

These two electric cars are clearly unsuitable for any normal transportation function. But the main safety and design problems are solvable, either in these cars or in future competitors.

Whether there is any future for the concept of electric cars probably depends on how well they compete in fuel economy and cleanliness with vehicles powered by internal combustion engines. At this point, electric cars are no cheaper to run than such economical subcompacts as the *Honda Civic CVCC* and the *Volkswagen Rabbit*—at least not where electricity is costly. And, of course, those two subcompacts and others like them are not limited to trips of under 30 miles at speeds of less than 30 mph.

The cleanliness of electric cars is another open question. Electric cars themselves produce no air-fouling emissions. But most of the generating plants that produce the electricity needed to recharge the car's batteries do produce emissions. Advocates of the electric car maintain that generating plants are more efficient than the internal-combustion engine, and that generating plants can disperse emissions high into the atmosphere, rather than concentrating them in city streets. Others, however, point out that wide use of electric cars might require double or triple the present electrical generating capacity of the country. At this writing, Congress is considering initiating a program, under the authority of the Energy Research and Development Administration, to explore further the feasibility of electric vehicles. Such exploration is obviously required.

CHRYSLER CORPORATION,
Detroit, Mich., October 2, 1975.

Hon. FRANK E. MOSS,
Chairman, Subcommittee for Consumers, Committee on Commerce, U.S. Senate, Washington, D.C.

DEAR SENATOR MOSS: This is in reply to your recent letter to J. J. Riccardo, Chairman of the Board, Chrysler Corporation, inviting us to comment on S. 1632 and H.R. 8800, the Electric Vehicle Research, Development and Demonstration Act of 1975.

Attached is a statement giving Chrysler Corporation's views on electric vehicles and legislation being considered. The statement also answers most of the questions submitted with your letter. We hope it will be useful to you and the Committee in your deliberations on these bills.

We request that the statement be included in the record of the Senate Commerce Committee's hearings on electric vehicles.

Sincerely,

J. D. WITHROW, Jr.,
Director-Research.

Attachment.

CHRYSLER CORPORATION COMMENTS ON S. 1632 AND H.R. 8800

As a manufacturer of motor vehicles Chrysler Corporation is fully aware of the necessity of reducing transportation energy requirements, particularly as they relate to petroleum products. To this end, we have maintained a substantial research and development effort on alternate power plants, including electric vehicles as well as fuel cell and battery research.

In time we believe that electric vehicles will play an increasingly important role in private transportation. However, there is much fundamental research and engineering development that has to be done to improve the limited performance currently available in electric vehicles, before they will meet with general public acceptance. Therefore, while we feel that the objectives of S. 1632 insofar as they promote the technologies necessary to the development of a successful electric vehicle are to be commended, we cannot agree that a purchase demonstration plan using currently available vehicles is the optimum way of encouraging the necessary development. Our assessment is that currently available electric vehicles powered with lead-acid batteries can be used efficiently only in specialized applications with limited ranges, such as urban mass transit, delivery and service vehicles. Present performance of currently available electric passenger cars is not adequate for safe intermixture with regular vehicles in normal urban and suburban traffic. In our view their operations would be best limited to restricted rights of way, such as in resorts and retirement villages. The energy available from lead-acid batteries, and the energy required, regardless of source, for a safe, minimally acceptable vehicle (in terms of performance, traffic mixing, etc.) differ by a factor of from 4 to 10. Use of electrical accessories would further widen this gap; passenger compartment heating would almost certainly require f . fuels. We feel that these conclusions have been demonstrated by Chrysler

and others, and well documented in the literature, and indicate that immediate large scale demonstrations of available electric passenger vehicles would serve no purpose in advancing technology, but would rather show the limitations of the present state-of-the-art, and may inhibit public acceptance.

We would like to suggest an alternate course of action which in our opinion would lead more rapidly to a vehicle accepted by the public, and suitable to a mass market.

As stated before, we believe that stored electrical energy is one viable alternative to the present internal combustion engine in certain applications, but only if such a vehicle can compete on near equal terms with a heat-engined counterpart, size for size. In our opinion, this cannot be done by simple adaptation or conversion of existing vehicles to electric power. To realize the full potential of electric vehicles, it will be necessary to undertake, or continue substantially funded research and engineering development programs on:

—Improved batteries, including advanced lead acid and alkaline cells for the short and near term, and molten salt for the longer term.

—Light weight, high efficiency traction motors, and associated power trains, including transmissions.

—Design of light weight vehicle structure and running gear, with maximum strength/weight ratio, reduced needs for power assists, and minimum aerodynamic and road losses.

Such a program, undertaken and administered by E.R.D.A. would be a more rapid and cost effective method of introducing a more viable electric vehicle, than premature mass demonstrations of current technology.

In parallel with, and possible preceding these technical developments, a study should be made of the nationwide role of the electric vehicle, as has been done for the Los Angeles area. Inputs concerning the most likely usage of a vehicle may affect the direction of research programs. It is not anticipated that within the next 8–12 years any single electric vehicle can be built as a specific replacement for most passenger cars. It is more likely that the first generation of electric passenger vehicles will be sub-compacts, increasing in size where necessary as energy storage systems improve.

In offering the foregoing alternate to an immediate purchase/demonstration of electric passenger vehicles we have been guided by our engineering judgment, experience and knowledge of other alternate power plants, the state-of-the-art of electro chemistry as it pertains to energy sources, and the economics of the marketplace. It is our opinion that the magnitude and long-term nature of the research still required is such that it is appropriate to have Federal government support. Equally, given the requisite technology, the introduction of a new product can best be left to private industry.

In the above general discussion, we have addressed some of the points raised in your questions particularly in regards to the program approach. The following offers further comments on some of the technical questions.

Even with possible improvements in energy density and cycle-life, we do not feel that the lead-acid battery is a serious contender as a means of energy storage. Nickel-zinc is the best candidate for a near term (1980?) "stop-gap" vehicle battery, but the energy density (88 watt-hours/kg) is only about twice that of the lead-acid cell. Cycle life is still a problem and nickel is not a low cost material. For the longer term (1985–1990) the molten salt lithium-sulfur and sodium sulfur cell may achieve 300–350 watt-hours/kg. In both these and similar cells, the operating temperatures of 700–1200° F pose severe engineering problems. Assuming no safety problems, this energy density would be adequate for a medium to light weight vehicle. In both cases, the time table would depend greatly on the level of research funding. Given the present level of public and private funding, it is our opinion that there will not be adequate improvements in the most promising developmental batteries (sodimum sulphur, lithium-sulfur and lithium-chloride).

The hybrid vehicle has been offered as a power plant combining the best features of the I. C. and electric power plants, but, again based on our own engineering information, and the results of several government funded studies (AiResearch, TRW, Hamilton, etc.) as well as the most recent Ford funded study by J. P. L. on Alternate Power Plants, we feel that the hybrid vehicle cannot meet any reasonable cost benefit criteria, and shows little, if any, advantage with respect to emissions and fuel economy, Hybrid vehicles, and at this time, even electric vehicles, would not offer any major reduction in petroleum consumption and will probably increase total (all fuels) energy consump-

tion. Total environmental impact with fossil fueled power plants would not be lessened; simply transferred back to the central power station.

Further, based on our engineering judgment and experience, as well as that of others, most recently the Jet Propulsion Laboratory of the University of California, we believe that other power plants, such as the gas turbine, Stirling, Diesel and certain types of stratified charge engines have the potential for greater fuel savings.

As for the required infrastructure, this would be a major long range problem correlative to any transportation system with a significant electric vehicle component. It is an excellent example of the type of problem that must be confronted and solved *before* embarking on a large purchase/demonstration program of the scope set out in S. 1632. A gradual, orderly increase in the electric vehicle population will bring in its wake public charging facilities sponsored by local government and private sector entrepreneurs. Service facilities would grow with private dealerships.

SUMMARY

A mass purchase of available electric passenger car vehicles, and those likely to be obtainable in the next 18–24 months, would serve no purpose other than to confirm presently documented problems and limitations.

Substantial funding for energy storage research and development would be more productive in accelerating the introduction of an electric vehicle that could compete economically in the private transportation sector. Parallel, unbiased studies on a national scale could define the probable role of various electric vehicles, and resolve the presently clouded issues of *total* energy and environmental impacts.

The total welfare of the country would be best served by government support of the substantial research and development required to realize a viable electric vehicle, rather than the premature, subsidized introduction of an at best marginal product.

When a viable electric vehicle results from the products of this recommended research, the economies of the marketplace and the competitive nature of American industry will combine to dictate the prompt production of this, or any product, which can truly serve the public need.

C&D Batteries Division,
Industrial Batteries and Chargers,
Plymouth Meeting Pa., October 6, 1975.

Hon. Frank E. Moss,
Committee on Commerce,
U.S. Senate,
Washington, D.C.

Dear Senator Moss: Recently we obtained, through the Electric Vehicle Council, a copy of the Bill you introduced, S. 1632: "Electric Vehicle Research, Development, and Demonstration Act of 1975". You have obviously accomplished a thorough examination and summary of the needs that must be met if the worthwhile goals of: promoting electric vehicle technologies and demonstrating the commercial feasibility of electric vehicles are to be achieved in the near future.

We wholeheartedly endorse your efforts and support the enactment of this bill, believing that its passage will provide a new catalyst for further development and promotion of electric road vehicle usage in the United States. Already, there are signs that off-shore electric vehicle technology is moving forward at a rapid pace, and may be imported to fill a domestic void.

C & D Batteries Division has a full, continuing interest in developing and applying improved battery energy storage systems; we have internal as well as joint research projects currently underway to this end. We do conclude as one result, that the lead acid battery is the only electric vehicle on-board energy source that can be counted on for at least the next three to five years.

We are happy to have the opportunity as part of the industry interest in the development of electric road vehicles, to respond in part to the pertinent questions relative to your Bill also forwarded to us. Our comments fall on those questions that we feel qualified to give answers to based on our involvement to the present:

Question No. 1. What changes or additions would you make to S. 1632 or H.R. 8800? Answer: I believe that the Senate and House Bills (S. 1632 and H.R. 8800),

is presently written essentially answer to our pressing domestic need to act, both from an action-planning and timetable standpoint.

Question No. 2. What specific benefits do you see arising from such a demonstration program?

Answer. I see the benefits arising from the program as two-fold:

(*a*) Providing sufficient base of manufacturing activity for optimizing the performance as well as operating efficiency of each vehicle component, and the total electric vehicle system.

(*b*) Providing an in-depth analysis of industrial, commercial and private vehicle usage environments well suited to the electric hybrid vehicle performance capabilities projected for the next 3–5 years.

Question No. 3. Some electric vehicle proponents raise the concern that "premature" demonstration might lead to a negative public perception of electric vehicle potential due to alleged limited cost and performance characteristics of existing electric vehicles. Do you agree or disagree that this danger exists? If you agree, how might the demonstration program be restructured to avoid this problem? If you disagree, please indicate why.

Answer. I do not believe the demonstration program will lead to negative public perception of electric vehicle potential if the program is properly implemented to yield the benefits described in Answer No. 2.

Question No. 4. Is one year a sufficient time in which to purchase and evaluate a baseline electric vehicle fleet of 200 to 300 vehicles, and develop performance criteria for purchase number 2? If not, what time frames would you suggest?

Answer. The one year time period for purchase of a base line electric vehicle fleet should be sufficient; however, a centrally coordinated effort that avoids over-influence of special interests is needed.

Question No. 5. Are the time schedules for purchases number 2 and 3 appropriate? Please explain.

Answer. Yes: It is not likely that any battery technology useful for electric vehicle, other than lead acid, will be developed within the next 3–5 years. We believe that industrial grade lead acid batteries can be designed and produced within 3–4 years, with at least 50% greater performance and twice the service life of the "golf car" batteries commonly used in most electric road vehicles today. Also, technology for optimizing the remainder of the electric vehicle system is mature and can be implemented well within the time allotted.

Question No. 6. What, in your opinion, will be the state-of-the-art in electric and hybrid vehicles within 42 months of enactment of H.R. 8800, assuming enactment during 1975? What government policies would contribute most to commercialization of electric and hybrid vehicles?

Answer. I believe it is reasonable to expect the following performance for *commercially* available electric road vehicles within 42 months:

(*a*) Range of 70–75 miles at cruising speed of 55 mph under moderate grade conditions and temperate climate.

(*b*) Acceleration capability at least matching that of present gasoline powered vans and other bulk delivery vehicles.

(*c*) "Refueling" time reduced to 3 hours or less.

(*d*) Battery life of 800–1000 full (80%) discharge cycles.

We do not feel qualified to comment on hybrid vehicles.

We believe that encouraging and promoting the use of electric road vehicles in the Federal Government sector wherever they prove to be equal or superior in usage benefit to gasoline powered vehicles, would certainly help spur commercial use.

Question No. 7. In addition to battery research, where should a federal R&D program on electric and hybrid vehicles focus its efforts? How much funding should be provided for battery research and these other efforts duing the next 5 years?

Answer. To comment on lead acid battery research only, C & D Batteries Division has put together an informal proposal for electric road vehicle (lead acid) battery development and usage optimizing, totaling approximately $600,000 and coinciding with the 15 month/42 month timetable of the above Senate and House Bills.

Question No. 8. Are there other vehicle technologies that offer comparable reduction in petroleum consumption and reduction of environmental impact to that of electric and hybrid vehicles? If so, is the special emphasis given to electric and hybrid vehicles in S. 1632 and H.R. 8800 justified? Please explain.

Answer. Not qualified to comment.

Question No. 9. How can an adequate manufacturing base and adequate competition be assured in electric vehicle production? Do S. 1632 and H.R. 8800 adequately address these needs? What changes or new provisions might be useful in this regard, if any?

Answer. Not qualified to comment.

Question No. 10. What infrastructure (for example, public or private recharging stations, maintenance and service facilities, etc.) must be developed to support the demonstration program called for in S. 1632 and H.R. 8800? What problems might be anticipated in establishing such an infrastructure?

Answer. I believe that the basic nucleus or potential for this infrastructure already exists for industrial and commercial markets, in present Company-sponsored and independent electric vehicle dealers (e.g. electric fork lift trucks), as well as lead acid battery service stations. Also, many large industrial potential users of electric road vehicles are already using and maintaining in-plant electric vehicles, so electric road vehicle maintenance should not pose any hardship.

For the private user market, the lead acid battery must emerge as highly reliable (no premature failures) and virtually maintenance free (automatic or semi-automatic watering).

Further, when and where an adequate market for "electric fuel" develops, I believe present gasoline vehicle service stations will expand their coverage to electric vehicles as well, offering such services as:

(*a*) Battery leasing and rental,

(*b*) Battery exchange for immediate refueling.

(*c*) Minor battery repairs and other routine electric vehicle maintenance.

Question No. 11. What are the performance characteristics of current technology electric vehicles? What improvements in lead acid battery technology do you foresee in the next 5 and 10 year periods? What are the implications of these improvements for the performance characteristics and purchase and life cycle cost of electric vehicles?

Answer. I believe I have already answered this question except to state that present commercially available electric road vehicles probably have a range of 30–40 miles at 40–30 mph.

Question No. 12. In your opinion, what other batteries show promise of future use in electric vehicles, and on what time tables? What performance characteristics and costs will be associated with the use of these other batteries?

Answer. The attached listing of electric road vehicle battery systems under consideration published last year in probably as current a summary as can be gathered, except that the projected availability dates for future types have moved out at least another year. Note also that these dates are for laboraory prototypes, not for commercially available, reliable on-board batteries.

Question No. 13. What problems or constraints might arise in large scale manufacture of electric cars with respect to production equipment and manpower skills? What problems might be anticipated by electric vehicle manufacturers in the areas of materials or capital availability?

Answer. Not qualified to comment.

Question No. 14. Please state your views on the current and future applicability of safety standards and regulations to electric and hybrid vehicles.

Answer: Not qualified to comment.

Question No. 15. What steps might the federal government take to facilitate introduction of demonstration electric and hybrid vehicles into state and local government fleets?

Answer. The Federal Government can certainly encourage the use of electric road vehicles through current and future programs involving project grants and other support. Beyond this. I believe the electric road vehicle must and will sell its own usefulness and benefits when it is design-optimized and properly applied.

Question No. 16. What institutional impediments do you see to the widespread introduction of electric vehicles?

Answer. Americans size up the electric road vehicle as not a good buy (higher cost—lower performance) when compared to its counterpart gasoline vehicle. This will generally continue to be true for the foreseeable future without substantial action such as proposed by Senate Bill S. 1632, and aimed at that portion of the market where the electric vehicle can effectively prove itself. This market segment may be as high as 20% of the total present domestic vehicle market.

We will be pleased to provide further information that you andyour collegues may feel useful. Thank you for your attention.

Cordially,

EDWIN C. READ,
Manager—Marketing Research.

SOME ELECTRIC ROAD VEHICLE BATTERY SYSTEMS UNDER CONSIDERATION[1]

System	Projected maximum performance, watts — Hours per pound	Per pound	Dollars per kilowatt-hour	Cycle life	Problem areas	Projected availability
Conventional batteries:						
Lead acid	15–25	20–30	20–50	300–2000	Low-energy density	Now
Nickel-iron	20–30	60	20–30	300–400	Gassing, maintenance	1976
Nickel-zinc	30–40	75–100+	20–25	250–350	Cost, life, dendrities	1977
Alkali-metal-high temperature:						
Sodium-sulphur (beta alumina).	80–100	80–100	20–40	2000	Construction electrolite life.	1980–85
Sodium-sulphur (glass)	80–150	80–400		2000	Life, glass stability	?
Lithium-sulphur	100	100+	20–40		Corrosion, cost, materials	1980–85
Other systems: Zinc-chlorine	60–75	50–60	10–20	500–2000	Complexity, hazards	1978–79

[1] "Automotive Industries," Apr. 15, 1974, p. 31.

American Automobile Association,
Falls Church, Va., October 6, 1975.

Hon. Frank E. Moss,
Chairman, Subcommittee for Consumers,
Committee on Commerce,
U.S. Senate,
Washington, D.C.

Dear Senator Moss: Your letter addressed to Mr. Norman Weiss has been referred to me for reply since my department has made a special study of electric vehicle technology and routinely follows progress of this promising, supplemental form of motor-vehicle transport.

I welcome the opportunity to comment on the following selected questions concerning S. 1632 and H.R. 8800:

Question 2. Principal benefit to be derived from a demonstration program will be the opportunity to convince the motoring public that (1) electric vehicles are not just novelties which have more exotic appeal than practical value, (2) that they are now being manufactured for sale and are available to the general public.

Question 3. Several small manufacturers have for several years produced and sold electric vehicles in this country, with at least limited success. Being introduced—as it would be—well after the fact, the demonstration program envisioned by S. 1632 could hardly be characterized as "premature." By providing substantial capital for improvement in both design and construction, the bill would produce a positive, rather than negative, "public perception of electric vehicle potential." It would assure continuous, visible improvement of the product, enhancing its appeal to the motoring public.

Question 7. Storage batteries obviously can, and must, be improved substantially if the electric vehicle industry is to gain a foothold in the marketplace of the immediate future. However, even most optimistic prospects reveal a system which is much too cumbersome and costly to be used as an energy source for an electric vehicle population of any real sophistication, size and importance in terms of energy conservation. Therefore, heavy emphasis should be placed on innovative, new systems such as super-cooled magnetic energy storage devices, and the balance of research concentration and funding shifted accordingly.

Question 10. Since a fundamental reason for supporting growth of an electric vehicle population is to maximize efficiency of public utility operations by encouraging night-time use, special attention should be given to development of re-charging facilities for the millions of privately-owned motor vehicles which, of necessity, are "garaged" at the curb. Outlets for emergency use exist in abundance, because of the number and ubiquity of service stations and garages. But special facilities would probably have to be installed at motels and hotels when cruising range, speed and safety characteristics of electric cars make overnight trips feasible.

Question 14. Until cruising range and speed encourage highway use, minimal safety standards might be acceptable. However, when electric vehicle technology has reached full-partner status in the system of passenger transport, relevant safety standard of maximum effectivenes should be applied.

Question16. Aside from the urgent need to improve battery storage capacity and reduce weight, the only "institutional impediments" of consequence should be those of a logistical nature—providing back-up systems required to sustain an electric vehicle population. However, none of these seems severe, in prospect. Electric current is available today, even in the remotest hamlet. And electric motors are a known quantity of elemental simplicity, by comparison with the internal combustion engine. They can easily be repaired or replaced by commercial sources which are found in most communities beyond village size.

Yours sincerely,

RICHARD F. CURRY,
Director, Environmental Affairs.

NATIONAL ACADEMY OF SCIENCES,
Washington, D.C., October 9, 1975.

Hon. FRANK E. MOSS,
Chairman, Subcommittee for Consumers,
Committee on Commerce,
U.S. Senate,
Washington, D.C.

DEAR SENATOR MOSS: This is in response to your request for views on S. 1632 and H.R. 8800, bills entitled the "Electric Vehicle Research, Development and Demonstration Act of 1975."

The National Academy of Sciences has had limited involvement in the study and consideration of the technological development of electric and hybrid vehicles. Under Sec. 6a of the Clean Air Amendment of 1971, the Academy was asked to study and report to the Congress and the Environmental Protection Agency on the technological feasibility of meeting the emission standards prescribed in that Act. As part of this study, the Academy also considered the state of technology of a number of alternative power systems and the potential they offer for emission reductions over that of conventional engines, including the consideration of costs, productivity and maintainability. Among these alternatives was the electric vehicle as a long-term alternative to vehicles powered by the internal combustion engine.

The November 1974 report of our Committee on Motor Vehicle Emissions concluded as follows:

"Based on present technology, it is feasible to manufacture electrically driven personal vehicles for low-performance (short range and low power) urban use. Even when equipped with the best currently available lead-acid storage batteries, these vehicles will have a high initial cost, low energy efficiency, and a high total cost per mile driven.

"The duty cycle of delivery vans and urban buses offer an attractive opportunity to introduce electric-powered vehicles with heavy-duty lead-acid storage batteries, even with the limitations of today's technology. Higher-energy and power-density batteries currently under development could make electric vehicles comparable in initial cost and superior in per-vehicle-mile cost than gasoline-engined vehicles. In view of the strong likelihood for a gradual shift toward coal, nuclear, geothermal, and, perhaps, solar primary energy sources, there are strong incentives for the development of advanced storage batteries and electrically propelled vehicles."

I have referred to these study conclusions to underscore the findings implicitly stated in S. 1632 and H.R. 8800 that for certain uses electric vehicles are today technologically feasible, and that for the long term the prospects are favorable for development of electrically driven personnel vehicles. The improved prospect for a future commercial market and related potentials for economies of scale, the rising costs of gasoline and regular maintenance for conventional internal combustion driven vehicles, and the concerns over energy conservation and air pollution, add to the favorable environment in which to assess the feasibility of electric vehicles. Certainly the Federal Government should pursue the option of the electric vehicle as one means of minimizing environmental problems, reducing dependence on foreign petroleum sources, and promoting long-range conservation of liquid fuel.

There are, however, several major deficiencies in present electric vehicle technology which lead, in my view, to the conclusion that a demonstration program at this time would perhaps be premature and would be unlikely to further substantially the state-of-the-art. The first technological barrier is the current reliance on lead-acid batteries and the need for additional research to develop

energy storage systems of much higher density and lower in weight than the lead/acid systems. The second area of needed research is in development of improved vehicle transmission systems. Without technological improvement in these two areas, it is unlikely that the electric vehicle will become competitive with the internal combustion engine vehicle, except as a specialist electric vehicle for freight deliveries, for vehicles employed in factories, hospitals, parks, etc., and on a more limited scale for powering urban buses. Electric vehicles are currently in use or being tested for these purposes.

In assessing the performance of present and anticipated electrically driven vehicles the studies by our Committee on Motor Vehicle Emissions provided a number of relevant conclusions with respect to these problems. Currently available lead-acid storage batteries have significantly higher initial costs and vehicle costs per mile than today's gasoline driven sub-compacts, with no improvement in overall energy efficiency. A substantial increase in the cycle life of lead-acid batteries could, perhaps, provide improved energy economy and lower vehicle costs per mile. It is unlikely, however, that significant long-term improvements can be achieved in the driving range of the lead-acid battery. It should be noted that recent advancements in the technology of alkali metal-sulfur systems offer substantial promise for technological breakthrough leading to development of high-energy, high power density battery systems. Prototype testing programs in the next several years should provide more definitive answers. However, production of significant numbers of electric vehicles based on alkali metal batteries, optimistically, cannot be expected for the next ten years.

Based upon reports and studies by our Committee on Motor Vehicle Emissions, it would seem that the most desirable and effective incentives could be achieved under a Federal promotional program designed to foster research and development of more efficient energy storage and transmission systems. Such a program, combined with a deliberate policy, as stated in the proposed measures, to favor the introduction of electric and hybrid vehicles into the vehicle fleet of Federal agencies, establishes, in my view, a constructive policy for promoting the development of commercially feasible electric and hybrid vehicles.

For the above reasons, I would urge that legislative priority be given by the Congress to those provisions of H.R. 8800 and S. 1632, which (1) foster research to promote the advancement in the technology of energy storage and transmission systems of electric and hybrid vehicles; and (2) provide for the introduction and use of advanced vehicle systems in the fleets of Federal agencies.

There is a final observation which I wish to underscore for your consideration concerning a conclusion set forth under the findings in H.R. 8800, that stationary sources of pollutants are potentially easier to control than moving vehicles, making it environmentally desirable for transportation systems to be powered from central sources. Although in principle this conclusion would seem correct, there remain inherent difficulties in controlling stationary sources of pollutants, especially the generation of power from coal and the problems related to the control of sulfur oxide emissions. If the Committee desires more information on this topic, a further discussion on this subject is set forth in *Air Quality and Stationary Source Emission Control*, a report by the National Research Council prepared for the Senate Public Works Committee, March 1975.

In conclusion, I should add that because of our limited experience with the programs proposed under S. 1632 and H.R. 8800, it seemed more appropriate to provide comments in the above manner rather than under the outline of questions in the enclosure accompanying your request for views. Also, I have enclosed copies of the appropriate reports of our Committee on Motor Vehicle Emissions which provide more details on the subjects under legislative consideration.

I am very pleased to provide these views for your consideration and hope they will be of use to your Committee.

Sincerely yours,

PHILIP HANDLER, *President*.

INTERNATIONAL LEAD ZINC RESEARCH ORGANIZATION, INC.,
New York, N.Y., October 9, 1975.

Hon. FRANK E. MOSS,
Committee on Commerce,
U.S. Senate,
Washington, D.C.

DEAR SENATOR MOSS: The Electric Vehicle Council has kindly forwarded your questionnaire on electric vehicles and I am glad to respond. There is not sufficient

time for me to provide you with the considered view of the industry represented by this organization. However, I put these views forward as opinions of one who has been connected with battery and vehicle research and development over a number of years.

ANSWERS TO QUESTIONS CONCERNING S. 1632 AND H.R. 8800 FORWARDED BY SENATOR MOSS

1. Emphasis in the bill should be placed on the electric multi-stop delivery van (or the electric bus) rather than the personal vehicle. Specifically, the wording under 1(a) should read "Within 2 years of enactment, contracts should be entered into for the purchase of a reasonable number of electric multi-stop commercial delivery vehicles for evaluation tests and initial demonstrations, the demonstrations to take place in fleet operation. (When operated in fleets, adequate technical supervision may reasonably be planned for, and routes can be preplanned so as to ensure that the vehicle range is adequate for each mission)."

At the same time, a number of vehicles designed for personal transportation should be purchased in order that suitable designs and initial performance standards may be developed.

(c) Within 2½ years of enactment, contracts would be entered into for purchase of at least 2,500 commercial vehicles meeting the criteria developed in b.

Item e should remain as stated.

2 and 3. The principal benefit would be to provide incentive to optimize the design and to encourage tooling up for large scale production. Significant overall improvement could be accomplished by relatively modest improvement in individual components, especially in: (a) batteries; (b) electric motors; (c) controls; (d) tires; and (e) optimization of component weight.

3. Provided that demonstration vehicles are placed in the hands of technically competent or carefully trained operators, and provided that they are operated on fixed routes, preferably in fleet operation for greater control, the vehicles would provide a demonstration of the simplicity of operation of the electrics and their low operating cost and increased reliability as compared with gasoline powered vehicles. This could only be anticipated if they are operated under these controlled conditions. Without proper control, I would not expect good results. At this stage of development, the electric vehicle will certainly not live up to the expectations of the average uninformed user as regards range and speed and, therefore, would probably be used in unsuitable situations.

A personal electric vehicle, whose battery is exhausted, would be highly visible on the roadside and a relatively small number of such cases would introduce prejudice into the minds of the general public. Therefore, the placing of the personal electric vehicle should be carefully restricted to those able to demonstrate a grasp of the limitations of the vehicle and the need for it to be used in a structured situation, such as commuting to work.

4. I would suggest a time frame of 2 years.

5. I would provide 2½ years for purchase number 2 in order to allow improvement in existing designs to be made and for these improvements to reach small scale production. Purchase number 3 I would be inclined to extend to 4 years. It is my belief that the prototypes and the small quantity production which we have seen so far do not represent design up to the present state of the art. For example, in many cases, the electric motor has not been especially designed for electric vehicles and therefore, operates at relatively low efficiency. Time would be needed to improve on this situation.

6. Within 42 months, the lead acid battery will remain the sole economic means of propulsion for electric vehicles. Its energy density will have been improved as compared with such propulsion batteries now in production by up to 20%. Just as important as energy storage capability of the battery is its cycle life. This will have been improved due to improved battery manufacturing techniques and charging equipment and procedures. The cycle life of the battery is extremely important because of its effect on maintenance costs.

Other batteries may become available for production. The first is likely to be the nickel-zinc battery followed possibly by a zinc-air battery. The economics in both cases will be less favorable than for lead acid and, therefore, these batteries will not be used where the vehicle can operate on a fixed route or with a restricted mission where a range limitation is not important. There are many applications where the limited range of the lead acid battery powered vehicle would be entirely adequate. The government policies which would help would include:

(a) Designation of zones within cities where exhaust emitting vehicles would be banned;

(b) Planning of roads to allow safe use of vehicles operating at relatively slow speeds;

(c) A tax structure to favor the use of electric vehicles;

(d) Utilities should differentiate in cost between peak and off-peak use of power, so that low cost electricity will be available for off-peak charging;

(e) Research and development on vehicle design;

(f) Placement of purchase orders adequate to allow manufacturers to defray cost of special tools for production of improved batteries etc.

7. Among hybrid vehicles the flywheel battery hybrid should receive attention. Regenerative braking is costly using electronic controls, however, the incorporation of a flywheel in the system would allow regenerative braking to be achieved at low cost. Batteries operate very inefficiently when subjected to very heavy power demand such as occurs during acceleration. A flywheel which has been trickle charged from the battery or charged by means of regenerative braking would act as a load leveller for the lead acid battery. By this means the range of an electric might be doubled.

Charging methods should be improved. The life of the lead acid battery so important to the economics of the project, can be considerably improved by refined methods of charging and these should be identified and special attention should be given to reducing the cost of charging equipment, and this applies especially to the charger capable of very high rates of charge such as a "gas" station might use.

Charging stations should be available to the electric vehicle driver en route in the same way that gas stations are available today. There should be facilities for charging at parking meters and in order that gas stations be able to give a heavy boost of charge to a number of vehicles, special planning will be needed to supply the necessary power.

An electric vehicle must be designed as an electric vehicle from the beginning. It must not be an adaptation of an existing vehicle design. The government could fund such projects as would improve overall vehicle design and importantly improve the efficiency of electric motors and reduce the cost of controls.

8. I know of no comparable means of reducing petroleum consumption. The special emphasis on the electric vehicle seems to me to be entirely justified.

9. Commercial demand for multi-stop electric *delivery vans* should be the first to be stimulated. Tax incentives would help in this regard. Refinements in design achieved through the electric delivery van program could then be applied to production of personal cars. The public must be educated to the reduced range and speed offered by the electrics and then steps could be taken to motivate them to purchase the electric vehicles.

10. An important development would be for service stations to sell power rather than batteries. A customer would exchange his batteries and pay only for the power used. The batteries would remain the property of the service station.

11. It is not possible to realistically discuss the performance characteristics of current technology electric vehicles without taking account of cost. Also the range of an electric is sensitive to the speed at which the vehicle is driven.

One elecric van now on the market (The Battronic) has provided when loaded a 60 mile range in city driving, including use of an expressway, at an average speed of 25 miles per hour. Its acceleration is comparable to other similar vehicles 0 to 30 miles per hour in 9.6 seconds. It provides a top speed of 60 miles per hour (at reduced range). Its curb weight is 5,800 lbs. empty of its load. It is powered by 2,200 lbs. of batteries.

Incremental improvements in all components of the vehicle would allow substantial improvement in this performance within the present state of the art.

In order that the price of a van be comparable to that of a conventional vehicle, it is desirable to accept more limited performance characteristics.

A study by Copper Development Association has shown that in 1975 a van capable of 40 miles per hour and 40 miles range should find a market of 326,000 vehicles in the U.S.A. This range should be doubled in the next five years using say 800 lbs. of improved lead acid batteries and with improvements in vehicle components.

In 5 years, there might be a 20% improvement in energy storage capability of the lead acid battery. Batteries cycle life should at the same time be considerably improved. At this stage of the technology, there is a trade off between energy storage capability and cycle life. With a 20% improvement in energy storage, it

should be possible to bring about a significant improvement in cycle life. It must be possible to bring about a significant improvement in cycle life. It must be recognized that the improvements suggested here are marginal improvements, and they do not take account of any possible breakthrough in technology. However, these taken together with improvement in the efficiency of electric motors and improved vehicle design could result in doubling the range of the electric vehicle, all other things being equal.

12. Within 5 years, there should be a nickel zinc battery available which might again double the range of the vehicle but this would be done at increased battery cost. There is a zinc air battery now being developed in France and elsewhere and this may have been proved economically viable in this period.

13. No response to this question.

14. To the extent that safety standards may increase the weight of the electric vehicle, they are likely to hinder its development. Such standards should realistically take into account the reduced speed and different method of operation of the electrics and should be accordingly less stringent.

15. Financial incentives would facilitate the introduction of demonstration electric and hybrid vehicles into state and local government fleets.

16. No response o this question.

Yours sincerely,

ALBERT R. COOK,
Manager, Electrochemistry.

DIE MESH CORP.,
Pelham, N.Y.

DIE MESH CORPORATION'S ANSWERS TO ELECTRIC VEHICLE QUESTIONNAIRE

Answering Question 1:

Section 11 of HR8800 entitled Loan Guaranties is satisfactory, with the exception that subdivision (c), which guaranties only 90% of the loan made by a participating bank, should be eliminated. If the loan guarantee provision of this bill is to mean anything, the Federal guarantee should be 100%, or else it is virtually certain that there will be very few banks that will participate in this program. No bank will risk 10%, 5%, or even 1% on a relatively new venture such as the electric vehicle project as set forth in this bill. From our personal experience in approaching banks to become involved in the electric vehicle project, we were issued a swift turn-down. Banks will not finance a new venture and if they are exposed to even a 10% risk, they will definitely not participate in this program. However, if the loan is guaranteed 100% we are sure that we or any other technically qualified company will have no problem obtaining an immediate loan so that we may begin preparing our company to meet the aims of this bill, pending the implementation by ERDA of the financial arrangements between the various companies that will be involved. Further, any loans that individual, technically qualified companies are able to obtain on their own should be supplemented initially with advance monies under this bill, so that all the necessary initial preparation that the companies will have to undergo will not be delayed by lack of funds.

Answering Question 2 and 3:

From this demonstration program will evolve new ideas and developments not now envisioned into such components as motors, controls and batteries. Further, there will be standardization of the basic hardware and electrical components that are necessary for the electric vehicle, thereby facilitating its manufacture. The demonstration program at this point cannot be premature, because electric vehicles as they exist today are capable of playing a very definite role in the transportation habits of our society. The demonstration program under this bill will also be an education program, whereby the people realize the limitations of the electric vehicle and at the same time learn that there is a vast segment of our population that can very easily use an electric vehicle due to their limited driving patterns. Further, as the program is implemented, there will be new developments made in the electric vehicle which will decrease its limitations and thereby increase its useability. Unless these vehicles are made and placed on the road continuously, progress will be low in forthcoming. Therefore, with the implementation of this bill it will be seen that things will start to happen very quickly in this young industry.

Answering question 4:

One year is sufficient time in which to purchase and evaluate a baseline electric vehicle fleet of 200 to 300 vehicles and develop performance criteria for purchase number 2, provided sufficient capital is allowed to complete a project of this kind without penalties.

Answering Question 5:

The time schedules for purchases number 2 and 3 are appropriate, provided sufficient capital is allowed to complete a project of this kind without penalties. It must be realized that the electric vehicle industry has, throughout its history, been hampered by lack of sufficient capital to actually do the proper job in manufacturing electric vehicles. Therefore, corners always had to be cut, components had to be improvised and converted, instead of being specifically designed and built for an electric vehicle. If this program is to be a success and we in the industry are to do the job "the right way", the capital insufficiency must be eliminated, and we must have the proper funds to do the right job. Therefore, the schedules as set forth in these bills is satisfactory if sufficient money is made available, thereby allowing us for the first time to stop all this improvisation and conversion.

Answering Question 6:

The goal of this bill should be to place technically qualified companies that have had "on the road" experience with electric vehicles over the past years in full production. Consequently, when the project under this bill is completed, these companies will be fully capable of continuing the mass production of electric vehicles to meet the consumer demand, which should be substantial by the time this program is completed. To predict the advancements that will be born out of this bill at this time is impossible, because they can only come through the hard work that is necessary to implement all the aims of this bill. However, at the end of four (4) years we can guarantee that those advancements will be numerous, and as a result thereof we firmly believe the electric vehicle will have captured the imagination of the consumer.

Answering Question 7:

This bill should definitely not single out any one component as the "hero" of electric vehicle advancement. This bill should concern itself with all areas where technological advancements can be made, such as first and foremost the electric motor, body weight, batteries, controls, charging units, standard charging stations, repair stations, replacement characteristics and standardizaion of parts common to all electric vehicles. The battery should receive no special attention at this time, for if it is made the key to success it will conflict with the established aims of this bill. The battery should take its place as an acceptable component that may, through this grant, improve or produce a new technology. Success in this project will first come from basic improvements, and then through new ideas and inventions.

Answering Question 8:

To our knowledge, there are no other vehicle technologies that offer comparable reduction in petroleum consumption and reduction of environmental impact to that of electric vehicles.

Answering Question 9:

This program should not be implemented on a bid basis. For the best results, technically qualified companies should be chosen to participate. The best means will be to give each company that is qualified the same amount of vehicles to product and also to provide three advance prototype models. At this point, it should be noted that this project not include newcomers to the electric vehicle industry, because they would require at least a three-year test period from the point that they perfected their electrical drive system. Only then can they even begin to order the necessary components to produce their vehicles on a mass scale. Only companies that have had "on the road experience" can make a success out of this bill. The Administrator should be made aware of the fact that if the financing under this bill is diluted to too many companies, or if inexperienced companies are chosen to participate, then it is doomed to failure. The qualified companies should be allotted equal capital and assigned the same goals at each phase of this project. Those that survive and produce a superior product should be given further support, if necessary.

Answering Question 10:

Firstly, the vehicles should be distributed in the same geographical area in the beginning of this project, to facilitate maintenance, repair and recharging. In each geographical area, there should be strategically located plug-in stations, combined with parking meters, so that the consumer can recharge the vehicle after it leaves the home garage.

Answering Question 11:

We can only refer to the Die Mesh electric vehicles, which have obtained a range between 25 to 35 miles, using a 2,600 pound vehicle with top speed of 50 miles per hour. Further, we envision that the lead acid battery can, with certain improvements, give a 30% increase in yield and provide an improved life cycle. However, we do not see any miraculous break-through giving a tremendously increased yield with the lead cell battery. As it exists today and with the suggested improvements that the electric vehicle makers can give to the battery manufacturers, we feel that these batteries can do the job as envisioned under this bill.

Answering Question 12:

This question should be directed to battery companies. However, in the area of motors, the Die Mesh Corporation feels that with the improvement of this component, specifically designed for an electric vehicle, the range of an electric vehicle could increase from its present range to between 90 and 100 miles on a single charge with the existing lead cell batteries. This advancement in the motor design will also give excellent performance to an electric vehicle equal in safety to the internal combustion engine. The Die Mesh Corporation feels that its new invention in electric motors known as the "Modularized Electric Motor", which is briefly explained in the text of the testimony of Domenic Borello to the Senate Commerce Committee on October 10, 1975, along with the accompanying copy of the disclosure document filed by Die Mesh Corporation with the U.S. Patent Office, is a major break-through in electric motors and will give an electric vehicle the aforesaid range, if not more, after it is fully implemented into said vehicle.

Answering Question 13:

Any problems or constraints that might arise in large scale manufacture of electric cars with respect to production equipment and manpower skills would relate to the definition of time and demand, and could be reduced if the government demonstrates to the public and the financial world its long-range support and acceptance of electric vehicles. This would provide the additional capital after this program is completed. As to the material, it would remain the same for an electric vehicle as it is in an internal combustion vehicle, most metals being able to be recycled in the electric vehicle.

Answering Question 14:

We have not had any experience with hybrids, nor have we seen any being used daily on the road. However, electric vehicles would not differ in safety as compared to the internal combustion vehicle if electric vehicle manufacturers had sufficient funds to properly put together said vehicle. (See "NOTE", page 6.)

Answering Question 15:

The Federal Government should purchase electric vehicles for immediate use in local areas by governmental employees, wherever possible, and in some fashion show on said vehicle that it is an electric vehicle.

Answering Question 16:

The only impediment we see to the widespread introduction of electric vehicles is the temporary adjustment to range and speed.

NOTE.—As it is not our purpose to discourage different types of vehicles, we suggest that you consider what a hybrid consists of before it is made a part of this electric vehicle bill:

1. A complete electrical system combined with a complete gas engine system, including gasoline fuel.
2. It must perform equally to other types of electric vehicles, in spite of the fact that it is carrying the gas engine system plus gas.
3. It must perform equally to some other similar gas engine vehicles, in spite of the fact that it is carrying a complete electric vehicle system, including batteries.
4. It must include all of the safety factors for high speed vehicles.
5. It must be heavier and better-supported in its chassis design in order to carry the two systems simultaneously.

6. It will require both electrical and mechanical maintenance stations.
7. The "hybrid" may result in consuming gasoline and making pollution equal to a compact car gasoline engine, because of all the above factors, which is clearly in contradiction of the goals and aims of this bill.
The inclusion of the hybrid vehicle in this bill will severely dilute both the efforts and results that can be achieved in the next four (4) years in the electric vehicle. We can only state at this time that we have never seen an actual working model of a hybrid vehicle, and we feel this is due to the serious problems of the hybrid previously enumerated in items 1 through 7. However, if the government desires to develop a hybrid, these should be a separate bill designed specifically for hybrid vehicle technology.

GENERAL MOTORS CORPORATION,
Detroit, Mich., October 13, 1975.

HON. FRANK E. MOSS,
U.S. Senate,
Washington, D.C.

DEAR SENATOR MOSS: I am pleased to respond to your letter of September 19 to GM President E. M. Estes in which you requested answers to a list of 16 questions concerning electric vehicle research, development and demonstration.

Enclosed is a statement presented earlier this year before the House Subcommittee on Energy Research, Development and Demonstration on H.R. 5470, a bill similar to S. 1632 and H.R. 8800 that are before your Committee.

In the House statement, General Motors recommended that demonstration programs would not be appropriate at this time because the principal impediment to commercial feasibility of electric vehicles is the state of the art of battery technology. When more adequate batteries are developed government subsidies should not be required for there would be adequate incentives in the marketplace for the introduction, sale and purchase of battery-powered vehicles.

This being the case, we do not think it is appropriate to comment on the workings of a demonstration program. However, we are attaching answers to some of the questions raised by your staff to which we feel GM answers may provide information useful to the Committee

We would appreciate your including the attached statement in your hearing record.

Sincerely,

ROBERT F. MAGILL.

Enclosure.

Question 6. What, in your opinion, will be the state-of-the-art in electric and hybrid vehicles within 42 months of enactment of H.R. 8800, assuming enactment during 1975? What government policies would contribute most to commercialization of electric and hybrid vehicles?

Answer. As indicated in the GM testimony, we believe research into critical "bottlenecks" to electric vehicle development can advance the-state-of-the-art. The areas where government research would be helpful include electrode processes, electrode catalysis, battery materials and cell durability. The state-of-the-art in electric and hybrid vehicles at any future time will be highly dependent upon battery developments. It is likely that the most advanced battery available at the specified time would be zinc-nickel oxide. We would not anticipate significant advances in other electrical vehicle aspects in that time frame.

In addition to research on battery technology, both the Congress and the Administration should attempt to understand the appropriate role of electric vehicles in the nation's energy and environmental policies. Whether the electric car can make a significant contribution to realization of those policy goals will depend on issues far broader than the issue of the electric- vs. gasoline-powered cars.

The last paragraph of the GM statement on S. 1632 addresses the issue of commercial development of the electric car:

"As higher performance batteries with greater durability, power and energy storage capability at reasonable cost are developed, combined with increased electric power generation capacity based on nuclear power, battery-powered electric cars should become more competitive with alternates. When the economics of electric cars become more favorable, there will be no need for the expenditure of public funds to promote them. Our competitive system will ensure that the products are provided as the commercial opportunity develops."

Question 7. In addition to battery research, where should a federal R & D program on electric and hybrid vehicles focus its efforts? How much funding

should be provided for battery research and these other efforts during the next 5 years?

Answer. The following two paragraphs are from page 17 of the GM statement:

"The second area for useful government effort concerning the electric car is directed toward energy and traffic management considerations in which the government should and must carry the major responsibilities. Some of these issues and value judgments are beyond the appropriate role of business.

"It is important to understand the social, economic and environmental impact of electric vehicles on a nation where a shortage of electric power capacity is threatened. Studies of urban traffic problems and the effects of added congestion resulting from slower electric vehicles mixing with other vehicles are both necessary and desirable."

Question 8. Are there other vehicle technologies that offer comparable reduction in petroleum consumption and reduction of environmental impact to that of electric and hybrid vehicles? If so, is the special emphasis given to electric and hybrid vehicles in S. 1632 and H.R. 8800 justified? Please explain.

Answer. Whether electrification of transportation can contribute to environmental improvement and energy conservation will depend greatly on the source of energy used to generate electric power. Electric vehicles could contribute to conservation of petroleum only if the electric power used to charge batteries were generated from non-petroleum energy—nuclear power or coal.

With regard to environmental effects of electric power production in connection with electric vehicles use, see Attachment F to the GM statement, a report on "Impacts of Electric Car Use in St. Louis, Philadelphia and Los Angeles" by William Hamilton. The author concluded that coal-generated electric power for vehicles could seriously increase sulfur oxide levels. Sulfur oxides, on a pound for pound basis, are more toxic than auto emissions.

Therefore, emphasis on promoting use of electric vehicles is premature until such time as:

1. The electric power to charge batteries is generated from non-petroleum fuel.
2. Technology is developed to generate electric power from coal in an environmentally acceptable manner and questions of nuclear safety have been resolved.
3. More efficient electric storage batteries have been developed.

Question 9. How can an adequate manufacturing base and adequate competition be assured in electric vehicle production? Do S. 1632 and H.R. 8800 adequately address these needs? What changes or new provisions might be useful in this regard, if any?

Answer. General Motors believes that concern with questions such as these is premature. Until more efficient batteries are developed which place the electric car on a firmer competitive footing vis-a-vis gasoline powered cars, there is little incentive for private business to invest the capital necessary for production.

In the event the technological hurdles are overcome, we believe there will be adequate incentive to attract venture capital and opportunities for many new businesses to compete in a new industry.

Question 11. What are the performance characteristics of current technology electric vehicles? What improvements in lead-acid battery technology do you foresee in the next 5 and 10 year periods? What are the implications of these improvements for the performance characteristics and purchase and life cycle costs of electric vehicles?

Answer. See Attachment B of the GM statement which describes GM electric and hybrid vehicles.

While improvements in lead-acid batteries may be possible in the next 5 to 10 years, such improvements are difficult to forecast. Nevertheless, continued evolutionary improvements in batteries probably will occur.

It is important to bear in mind, however, that the energy density of lead acid batteries is only about 1% that of gasoline. Enormous improvements in battery technology would be required to overcome that relative handicap.

Question 12. In your opinion, what other batteries show promise of future use in electric vehicles, and on what timetables? What performance characteristics and costs will be associated with the use of these other batteries?

Zinc-nickel oxide batteries in the nearer term and sodium-sulfur and lithium-sulfur batteries in the longer range appear to offer the greatest promise of providing a reasonable combination of specific power, specific energy, durability and cost for future electric vehicles.

We would expect that the zinc-nickel oxide battery which may about double the energy density of the lead acid battery should be available in the late 1970's.

Sodium sulfur and lithium sulfur high temperature batteries, which may offer a six to eight fold improvement in energy density over lead acid batteries, may be developed to the point of commercial feasibility by the 1990's.

Question 13. What problems or constraints might arise in large scale manufacture of electric cars with respect to production equipment and manpower skills? What problems might be anticipated by electric vehicle manufacturers in the areas of materials or capital availability?

Answer. It is both premature and futile to speculate at this time about the problems which *might* arise if and when electric vehicles reach the stage of large scale production.

Even if technological problems with development of satisfactory batteries can be overcome, it is reasonable to assume that production of electric vehicles would begin on a very small scale and gradually expand as public acceptance of the new technology increases. Any problems with respect to production equipment, manpower skills, etc., could be expected to be solved as they have for hundreds of other new products that have been introduced into the economy.

Question 14. Please state your views on the current and future applicability of safety standards and regulations to electric and hybrid vehicles.

Answer. The typical electric car of today is substantially underpowered for safe driving in existing traffic, particularly on high-speed freeways; and they present difficult problems of traffic safety when mixed with conventional cars and trucks. Those safety problems, however, may be much less severe when electric vehicles are operated on low-speed residential streets, on "speed paths" in planned communities or in exclusive low-speed traffic lanes.

If electric vehicles and other relatively low-powered vehicles were to be restricted to certain low-speed traffic situations, consideration might be given to exempting them from certain safety standards applicable to high-speed vehicles. In this case, a study by the National Highway and Traffic Safety Administration as to selective exemption from safety standards for electric vehicles would be appropriate.

Question 16. What institutional impediments do you see to the widespread introduction of electric vehicles?

Answer. At this time, the institutional impediments to widespread introduction of electric vehicles are far less significant than the technological and economic roadblocks that impede their commercial development.

If those technological problems could be overcome, then studies of traffic management, traffic safety, electric generating capacity, availability of recharging stations and other problems or impediments to convenient use of electric vehicles could be conducted.

STATEMENT OF JAMES C. HOLZWARTH, TECHNICAL DIRECTOR, GENERAL MOTORS RESEARCH LABORATORIES, GENERAL MOTORS CORPORATION TO THE SUBCOMMITTEE ON ENERGY RESEARCH, DEVELOPMENT AND DEMONSTRATION OF THE HOUSE COMMITTEE ON SCIENCE AND TECHNOLOGY

Mr. Chairman and members of the House Subcommittee on Energy Research, Development and Demonstration, I am James C. Holzwarth, technical director, General Motors Research Laboratories. With me today is Paul D. Agarwal, head of Research Laboratories' Electrical Engineering Department. We appreciate the opportunity to comment on H.R. 5470.

As we move toward energy self-sufficiency, when resumably nearly all of our electric power will be derived from coal and/or nuclear sources, and large scale use of petroleum and natural gas by public utilities will no longer be needed, then the electric car may be an important contender in fulfilling our long-range transportation needs.

We believe that governmental backing could foreshorten the time required for developing electric propulsion technology to the stage of commercial feasibility. Furthermore, the government needs to pave the way for electric vehicles through enabling legislation as well as administrative action if electrics are to be permitted to enter into an existing vehicle population.

GM alternative power plant research and development

For many years, General Motors has committed substantial resources to developing alternatives to the current automobile engine. We are committing substantial effort and resources to alternate fuel engines, small diesels, gas turbines, stratified charge engines and other.[1–11] Our total alternative power source

research and engineering expenditures for 1975 are expected to be about 50 million dollars. These expenditures since 1967 are detailed in Attachment A.

Our efforts also include a great deal of work on propulsion systems with potential for the longer term future. Electric vehicles, of course, are in that category. At our Research Laboratories alone, about 30 people are working intensively on advanced propulsion batteries and fuel cells. We are carrying on basic research on electrode mechanisms and the electrode processes that lead to deterioration upon cycling. We are also carrying out research on materials for electrodes, separators and electrolytes, to minimize battery weight while achieving adequate life. Others in our Electrical Engineering Department at the General Motors Research Laboratories are looking at optimized electric drive systems, including traction motors, controls and electronics needed with these advanced batteries.

General Motors is also concerning itself with advanced battery design and manufacturing technology and with the projected costs for making these advanced battery systems. Engineers at our Engineering Staff and at our Research Laboratories are carrying out analytical studies to determine the levels of battery technology required before vehicles of various sizes, weights, ranges and performance capabilities can be considered. We feel that we will be prepared on the engineering and manufacturing details when advanced energy storage devices become feasible for production vehicles.

GM electric car experience

Over the past decade, we have built and tested a series of electric and hybrid vehicles using the most advanced state-of-the-art components, to develop and optimize motor and control systems, and to gain actual operating experience. Characteristics of these cars are documented in Attachment B.

We have also purchased or test driven electric vehicles manufactured by other companies. Even though we had high expectations with respect to these vehicles, the results frustratingly disappointing.

One simple and inexorable fact kept bringing us back to reality with every fresh look. Existing batteries, including the most energetic batteries commercially available, couldn't begin to do an effective job of moving people in comparison with gasoline.

The best lead-acid batteries available today with appropriate cycle life for propulsion power in passenger electric cars deliver only 20–30 watt-hours of electrical energy per kilogram, depending on the application. Although the peak efficiency from battery to wheels (motor, controls and driveline) can be as high as 85%, it will be no greater than 60% in stop-and-go traffic in city driving. Therefore, the lead acid batteries deliver only 12 to 18 watt hours of energy per kilogram at the wheels.

In contrast, gasoline has an energy density of 13,200 watt-hours per kilogram. Even if a conversion efficiency from the gas tank to the wheels for city driving, were assumed to be as low as 10%*, it would still deliver 1,300 watt-hours per kilogram at the wheels or about two orders of magnitude greater than for the lead-acid batteries. Even the best batteries envisioned today, which may be commercially available in the period around 1990 to 2000, will have only a 6- to 8-fold improvement in energy density over lead acid.

To place it in proper perspective, for the same work done at the wheels as by 20 gallons of gasoline (58 kilograms) in an internal combustion engine vehicle, one would require about 5,000 kilograms of lead acid batteries or 600–700 kilograms of the best projected batteries. It becomes obvious why electric cars will continue to be much heavier than their internal combustion engine counterparts designed for the same mission.

Because of this battery limitation, electric vehicles are unable to match the performance and range of gasoline powered vehicles. They suffer from greater weight, both the battery weight and necessary added vehicle structure, and this weight penalty demands more propulsion energy. In addition, the original cost is high, and, when amortization is considered, the operating cost also is high.

We have learned a great deal from our research on electric vehicles. However, the typical electric car of today is substantially underpowered for safe driving in existing traffic situations. Because of this, the driver's natural inclination would be to drive it "full-throttle" to try to get up to the maximum vehicle speed capability, which is usually at or below urban thoroughfare traffic speed. And

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*Average tested efficiency (from gas tank to wheels) for all 1975 cars for EPA urban driving cycle—by EPA laboratories, Ann Arbor, Michigan, 11.5%.

when he finally gets to that speed, he must keep his "foot to the floor" to maintain that speed. Because he is now draining the batteries at the "maximum rate," his operating range falls well below his expectation. After relatively few miles, his ability to maintain speed, or to accelerate again to traffic speed from a stopped position, begin to diminish. As the battery pack ages, vehicle performance falls off; as the battery pack loses charge, performance diminishes. In cold weather, both range and performance decrease.

In designing batteries for electric vehicles, there are tradeoffs among specific power, which determines vehicle performance, specific energy, which affects vehicle range, and battery life, which influences vehicle operating cost. The Electrovair II, shown on page 1, Attachment B, was built using silver-zinc batteries as a power source. It had good performance—it nearly matched the gasoline engine Corvair performance—and this made it effective in mixing with regular traffic. But this performance was attained at serious sacrifice of battery life and range capability.

Silver-zinc batteries would be impractical for wide transportation use because of high initial cost. The batteries in Electrovair II contained about $10,000 worth of silver at today's market prices. But they were chosen for the experiment because the technology for building them was available. In addition, they matched the performance capabilities expected from some of the advanced batteries now being developed for use beyond the next decade.

Our 512 electric vehicle, shown in Attachment B, used commercially available batteries, had a top speed capability of only 30–45 miles per hour and could not safely mix with existing traffic.

Incidentally, neither of the two cars would come close to meeting current Federal Motor Vehicle Safety Standards. If they were redesigned to conform to these standards, the added weight would further degrade their performance, range and operating economy. When vehicle weight is added to meet safety and or performance requirements, additional weight must be added to the chassis, drivetrain, suspension and other components to maintain vehicle performance and structural integrity.

Have we given up on electric propulsion? No, indeed! But for the present we feel that building more electric vehicles is a waste of resources. The real problem—and really the only technological roadblock to electric personal transportation—is the battery system itself. No technological breakthroughs are required for devising electric drive systems, motors, controls, choppers, inverters or other circuitry, although substantial engineering effort would be required to tailor these electrical components to individual vehicles. There are many ways available to design and build adequate hardware to fit specific vehicle needs.

We are now concentrating our efforts on basic electrochemical research and on engineering development of advanced batteries. Zinc-nickel oxide, sodium-sulfur and lithium-sulfur currently offer at least some promise of providing a reasonable combination of specific power, specific energy, durability and cost for future electric vehicles. We have looked at other systems as well—lithium-chlorine, zinc-air and zinc-chlorine, for example, and have considered these too costly or too impractical.

"Findings" of 5470

Mr. Chairman, Section 2 of H.R. 5470, the "findings" which presumably form the basis for this proposed legislation, contains a number of statements which are incomplete or inaccurate. Thus, they could provide erroneous conclusions about prevailing conditions and faulty assumptions on which to base legislative action. I would like to make some comments about these findings which, I hope, will contribute to a more balanced perspective of the role of battery-powered vehicles:

Finding No. 1

"Travel patterns of commercial and private vehicles in urban areas are weighted heavily toward short and predictable trips well within the capability of electric vehicles of current design;"

In a restricted transportation role, the battery-electric vehicle already has a place in our transportation system. It currently serves in golf carts, lift trucks and on-site people movers. Commercial urban delivery vehicles and buses for low speed, short range service with frequent stops are available and seem to perform satisfactorily in this specialized use. Downtown shoppers, commuters and "erranders" as well appear technically feasible today with lead-acid battery technology. This is not to say, however, that present travel patterns in urban areas

are within the capability of electric vehicles of current design. It must be remembered that when large numbers of small personal transportation vehicles are contemplated for use on streets as opposed to golf courses, factories and restricted commercial service, federal auto safety requirements would have to be met, and this will adversely affect their size, weight and cost. There are many other unanswered questions about the safety hazards involved in mixing extremely small, lightweight, low performance vehicles with today's conventional cars and trucks on urban streets and freeways.

FINDING NO. 2

"Our balance of payments and our economic stability are threatened by the need to import oil for the production of liquid fuel for gasoline-powered vehicles;"

Automobiles account for only about 13% of total energy use, and less than 30% of petroleum use. In 1974, we consumed 1,370 million barrels of oil for automobiles and 485 million barrels for electric power generation. We imported 2,240 million barrels. If all automobiles were to be removed from the streets, we would still need to import oil for other uses. If additional electric power required for charging the electric car batteries were to be generated from oil, rather than nuclear power or coal, any advantage in reducing oil imports would be substantially reduced.

The question of converting a substantial portion of our transportation system to electric power cannot be answered in isolation from other energy policy considerations. Any appreciable impact on petroleum imports from introducing electric vehicles can be achieved only gradually and in the long-range future—if it is found to be desirable as the nation's energy policies are defined.

FINDING NO. 3

"The shortage of fuel for gasoline-powered vehicles will continue indefinitely;"

It is inappropriate to single out gasoline-powered vehicles in this context so long as there are other uses of petroleum for which substitutes may be more readily available. This statement could just as plausibly be amended to read: "The shortage of fuel for gasoline-powered vehicles will continue indefinitely so long as major quantities of petroleum are used to generate electric power or for large industrial and commercial boiler fuel." The existence or continuation of any gasoline "shortage" involves considerations and definitions of present and future energy policy.

FINDING NO. 5

"The strain on individuals' budgets inflicted by liquid fuel prices mandates the development of an alternative source of propulsion wherever possible;"

This statement implies that the cost per mile of electric vehicle travel will be less than the cost per mile with gasoline. Our engineering studies indicate that this assumption may not be true. Because an electric vehicle is considerably heavier than its gasoline powered counterpart of equivalent performance, it requires about 40% more energy at the wheels. In addition, the cost to the consumer of energy in the form of electricity is much higher than the cost of energy as gasoline at current prices. Attachment C, Table I, for example, indicates that one million BTU's of electricity in the Detroit area in February, 1975, cost the consumer 1.88 times as much as one million BTU's in gasoline.

However, the onboard energy conversion efficiency of electric vehicles is over twice (2.3x) that of gasoline powered vehicles. The net result is that the energy cost to the operator of a small electric shopper would be about 15% more than the cost of gasoline for a similar internal combustion engined shopper ($1.4\times1.88/2.3=1.15$). Attachment D explains these issues in more detail.

FINDING NO. 7

"Stationary sources of pollutants are potentially easier to control than moving vehicles, making it environmentally desirable for transportation systems to be powered from central sources;"

Electric utilities that burn fossil fuels do emit pollutants—both oxides of nitrogen and sulfur oxides. Coal burning power plants emit these two pollutants at much higher levels.[12] According to EPA data,[13] sulfur oxides on a pound for pound basis are considered more injurious to health than conventional auto emissions.

Thus, while control methodology may be easier to apply, actual ambient air quality standards would probably be more difficult to achieve if electric cars supplanted the existing fleet of cars. Attachment E shows a comparison of the grams per mile pollution from gasoline-powered cars meeting 1976 and 1978 standards with electric cars using power from coal-burning power plants meeting EPA standards. On a health weighted equivalent basis, using the primary air quality standards established by EPA,[13] the electric car would result in from 2.3 to 12 times as much pollution in the air from power plants as from the exhaust of the gasoline-powered car. Of course it must be recognized that automobile exhaust is emitted close to the ground and largely in urban areas, while the effect of emissions from electric power plants depends largely on their location with respect to urban areas.

A report prepared by William Hamilton under contract to EPA, entitled "Impacts of Electric Car Use In St. Louis, Philadelphia, and Los Angeles," shows that an 80% electric car population in these cities in 1990 would have little effect in reducing hydrocarbon or CO levels, the principal automotive-related pollutants. Added electric power generation, however, would seriously increase sulfur oxide levels. This report has been included with our statement as Attachment F.

FINDING NO. 9

"Electric-powered vehicles do not emit any significant pollutants and are far less noisy than conventional automobiles and trucks;"

While we do not now know of significant pollutants emitted by battery-powered vehicles, some of the batteries being considered for future applications use sulfur, chlorine, nickle, zinc, lithium cadmium, sodium and other substances which may be introduced into the environment. The potential for environmental risk from these substances should not be dismissed.

FINDING NO. 11

"Because electric vehicles use little or no energy when stopped in urban traffic, they permit the conservation of energy currently wasted by conventional automobiles and trucks;"

This statement is not incorrect; but it is, to some extent, misleading. Energy would be required for heating in cold weather, even when the vehicle is stopped at traffic lights and for vehicle lighting, signalling, defrosting and other essential uses. These factors tend to reduce the miles that can be driven on a unit of fuel. It is appropriate, however, to compare the efficiency of electrics and conventional cars on an urban driving cycle. Comparisons in this testimony have been made on the basis of the EPA urban cycle in which 18% of the time is spent idling.

FINDING NO. 12

"The power demands of electric vehicles would promote energy conservation by loading utilities in off-peak late night hours, permitting more efficient use of plant capacity;"

Because electric cars are expected to continue to have limited range/performance characteristics, they will be relegated to short-trip shopping and commuter use. Most errands of this type are carried out during daytime hours, and the tendency would be to put them "on charge" as soon as the mission is completed, to make sure the vehicle will be ready for the next demand. If they are to be used for commuting, charging probably will be accomplished during the working day. Thus, while *some* battery charging would be done at night during off-peak hours (possibly encouraged by changes in rate structures favoring off-peak use), a great deal of this additional load would be likely to come during daylight and "peak" hours.

FINDING NO. 13

"The depressed state of the current automobile industry would be alleviated by the introduction of new technologies more closely matching consumer needs;"

This statement implies that technology exists today to provide electric powered vehicles that "more closely match consumer needs" than the vehicles presently available, and if those electric vehicles were made available, they would sell in large quantities.

We believe electric vehicles may play an increasing future role in our transportation system. But there is no basis for the implication that there is an exist-

ing market for electric cars of such magnitude as to alleviate "the depressed state of the current automobile industry." Considering the dynamic nature of the American economy, it is inconceivable that if a substantial opportunity to market electric cars existed, it would long be overlooked by the automobile industry or by other companies who could provide electric car entries.

Commercial feasibility

One stated purpose of H.R. 5470 is to "demonstrate the commercial feasibility of electric vehicles." Implicit in the term "commercial feasibility" is a demonstration of the salability of the product. Does the product fulfill people's wants and needs so that they will buy it? Surely, government subsidies for private individuals to encourage use of electric vehicles and government requirements that they be used by the Postal Service and the General Services Administration hardly demonstrate that they are desirable, salable products on their own merits.

The role of the Federal Government in electric propulsion R. & D.

General Motors does not believe that much can be gained at this time by subsidizing the sale of electric *vehicles.* The capability of electric vehicles with state-of-the-art battery technology is well known. Until better batteries are developed, those capabilities are not likely to be improved drastically.

We believe the production, at this time, of a significant number of electric vehicles would:

(a) Be costly and without real benefit;

(b) Be uninformative regarding the real problem—the batteries;

(c) Mix a low performance vehicle population with the current automotive population; and

(d) Not move us close to energy self-sufficiency in a reasonable time, since some petroleum conserved in the refining of less gasoline probably would merely be consumed in extra power plant generation, especially for peaking power.

The 352 electric vehicles currently being readied for the Postal Service should comprise an adequate sample to demonstrate capability and determine performance. Presumably these new vehicles employ the latest in commercial battery technology and will provide a test in service best suited to this type of vehicle.

We question the need for the government to subsidize products for sale in a competitive market. Private industry is better equipped and sufficiently motivated to respond to that phase of the problem. There is a role for government to play in supporting research and development on advanced battery and fuel cell technology where the real bottlenecks to commercial feasibility exist.

Electrode processes, electrode catalysis, development of better battery material and improved cell durabiity are areas which now represent critical bottlenecks in the industry's efforts on battery-powered cars. Government support of research in these areas would supplement rather than duplicate the efforts of industry and thus make real contributions to progress.

The second area for useful government effort concerning the electric car is directed toward energy and traffic management considerations in which the government should and must carry the major responsibilities. Some of these issues and value judgments are beyond the appropriate role of business.

It is important to understand the social, economic and environmental impact of electric vehicles on a nation where a shortage of electric power capacity is threatened. Studies of urban traffic problems and the effects of added congestion resulting from slower electric vehicles mixing with other vehicles are both necessary and desirable.

It would be advisable for Congress to have available a better understanding of a feasible and appropriate role for electric cars in the nation's energy policy before committing large amounts of public funds to promote widespread use of electric vehicles. When nuclear power and coal assume the dominant role in generating electrical power, then the electric car could begin to assume a more effective role in our nation's energy and transportation systems.

As higher performance batteries with greater durability, power and energy storage capability at reasonable cost are developed, combined with increased electric power generation capacity based on nuclear power, battery-powered electric cars should become more competitive with alternates. When the economics of electric cars become more favorable, there will be no need for the expenditure of public funds to promote them. Our competitive system will ensure that the products are provided as the commercial opportunity develops.

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11. "General Motors Request for Suspension of 1977 Federal Emissions Standards," submitted to U.S. Environmental Protection Agency, January 10, 1975.

12. *News Report*, National Academy of Sciences, National Research Council National Academy of Engineering, XXV No. 3, March 1975.

13. Federal Register, *36*, 8186 and 15486 (1971).

Attachment A

GENERAL MOTORS CORP. AUTOMOTIVE EMISSION CONTROL EXPENDITURES—TOTAL RESEARCH & ENGINEERING

[1967 through 1975, calendar year basis]

[In thousands]

Year	Current gasoline piston engines	Alternate power sources	Total
1967	$14,565	$3,511	$18,076
1968	18,010	7,977	25,987
1969	28,033	15,135	43,168
1970	43,978	19,098	63,076
1971	69,337	30,048	99,385
1972	81,536	32,952	114,488
1973	97,604	49,464	147,068
1974	87,626	49,296	136,922
Subtotal	440,689	207,481	648,170
1975 [1]	91,749	50,431	142,180
Total	532,438	257,912	790,350

[1] Estimated.

Note: Fuel economy research and development expenditures are included in the above numbers, but not segregated since General Motors records are not kept in this fashion.

ATTACHMENT B

GM

"EXPERIMENTAL" ELECTRIC AND ELECTRIC HYBRID VEHICLES

ELECTROVAIR I AND II

(Engineering Staff)

Program Started - January 1964:

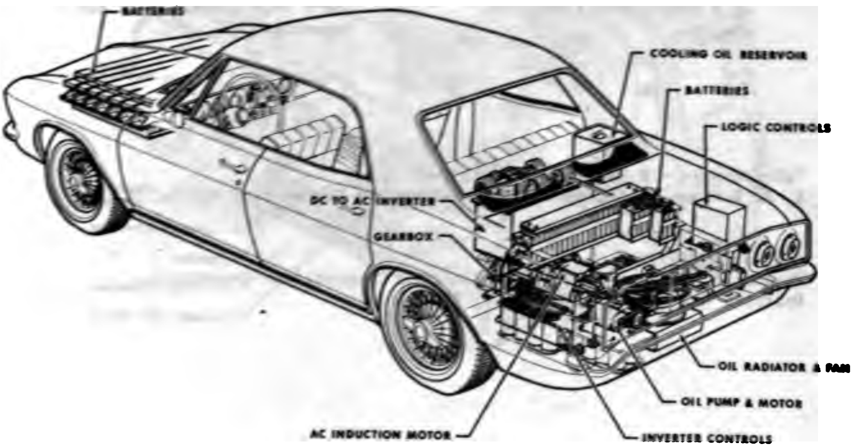
I. Operational - November 1964 (1964 Corvair)

II. Shown to public - October 1966; results presented January 1967 - SAE 670175; refined motor controls concepts. (1966 Corvair)

Power Train:

Battery Pack -	Silver-zinc - highest available energy storage and peak power output/lb. (Batteries purchased from Yardney Electric Corp.) Costly and limited cycle life; voltage - 530 V; 680 lb.
Motor -	AC induction - 100 HP - 13,000 rpm - 130 lb.
Controls -	18 SCR provides variable voltage and frequency.

Performance:	Electrovair II	Corvair
Weight	3400 lb	2600 lb
0-60 mph	16 sec	16 sec
Top speed	80 mph	86 mph
Range	40-80 miles	250-300 miles
Power Train Weight	1230 lb	610 lb



ELECTROVAIR I AND II
(Engineering Staff)

Features:	ADVANTAGES	DISADVANTAGES
	Good power density	Low range
	No exhaust emission	Very high cost
	Quiet operation	Long recharge time
		Short life

Conclusion: Program stopped January 1967. Further technological advances needed in electric power train - particularly in battery area.

Figure 1 - Electrovair I built on a 1964 Corvair body and chassis.

Figure 2 - Electrovair II built on a 1966 Corvair body and chassis.

"Electrovair - A Battery Electric Car"
E. A. Rishavy, W. D. Bond, T. A. Zechin, GM Engineering Staff.

SAE Paper 670175
Presented at SAE Automotive Engineering Congress and Exposition, Detroit, Michigan, January 9-13, 1967.

E L E C T R O V A N

(Engineering Staff)

Program Started - August 1964:

Shown October 1966; results presented January 1967 - SAE 670176 and 670181.

Power Train:

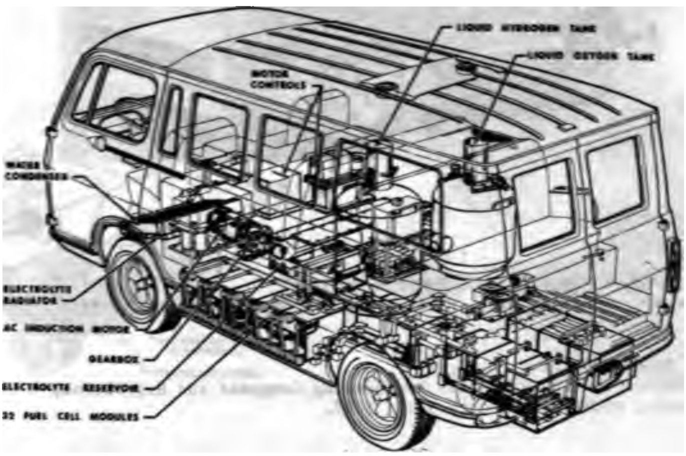
Fuel Cell - H_2-O_2 (largest H_2-O_2 fuel cell of its kind in world)	Developed and built by Union Carbide Corp. Fuel cell discussions were concluded with Allis Chalmers, General Electric, Pratt and Whitney, Esso and Union Carbide. Pratt and Whitney and Union Carbide were given phase 1 contracts to build 1 KW_e units. Union Carbide supplied fuel cell hardware for Electrovan. 32 modules - 1 kW/module continuous 42#/each (dry); 5 kW/module peak; voltage - 520 V.
Motor and Controls	Very similar to Electrovair II.

Test Bed:

1966 GMC Handivan

Performance:

Total Weight - 7100 lb
Power Train Weight - 3930 lb
Top Speed - 70 mph
0-60 mph - 30 sec
Range - 150 miles



E L E C T R O V A N

(Engineering Staff)

Features:

ADVANTAGES	DISADVANTAGES
High efficiency	High weight
Good range	Very high cost
Quick refuel	Low power/weight
No exhaust emission	Complex
Quiet operation	Safety
	Short life

Conclusion: Program stopped January 1967. Further significant technological advances needed in fuel cell areas of economics, power per unit of weight.

"Electrovan - A Fuel Cell Powered Vehicle"
C. Marks, E. A. Rishavy, F. A. Wyczalek, GM Engineering Staff.

SAE Paper 670176
Presented at SAE Automotive Engineering Congress and Exposition, Detroit, Michigan, January 9-13, 1967.

512 URBAN CAR

(Engineering Staff)

Program Started - December 1966

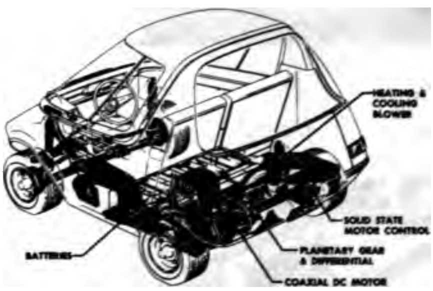
Shown - May 1969; results presented May 1969 - SAE 690461.

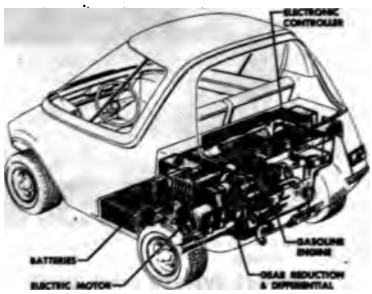
Power Train:

Lead-Acid Battery -	Deep discharge, lightweight (Delco-Remy) 330 lb; 84 V.
Motor and Controls -	DC series (Delco-Remy) - 54 lb 8-1/2 HP at 4000 rpm continuous.
	Solid state controller (Delco-Remy)

Performance:

Weight	1250 lb
Power Train Weight	575 lb
Top Speed	45 mph
0-30 mph	12 sec
Range at 30 mph	47 miles





ELECTRIC CAR

HYBRID CAR

512 URBAN CAR

(Engineering Staff)

Features:

ADVANTAGES	DISADVANTAGES
Special purpose vehicle	Low range
No exhaust emissions	High weight
Very small size	Cannot mix with conventional traffic patterns
Minimize - traffic problem	
- parking problem	
Quiet operation	

Conclusion: Program stopped April 1969. Further improvements in electric power train technology needed to satisfy urban car performance and economic needs.

Figure 3 - The electric powerplant is installed in the final body configuration, the gasoline engine in a sport roadster version, and the hybrid in an early test bed vehicle.

"Special Purpose Urban Cars"
J. J. Gumbleton, D. L. Frank, S. L. Genslak, A. G. Lucas, GM Engineering Staff.

SAE Paper 690461 - Presented at SAE Mid-Year Meeting, Chicago, Illinois, May 19-23, 1969.

X E P - 1 A

(GM Research)

Program Started - 1968: Operational - April 1970. Shown - June 1970.
Results presented January 1971--SAE 710234 and 719014.

Power Train:

Powerplant - (Dual Battery)

Zinc-Air (GMR)* - 20 kW; 27 kWh; 648 lb.
Provides the energy and power for cruising to 60 mph; recharges the Pb-acid battery pack.

Lead-Acid (Delco-Remy-GMR) - 20 kW; 1.6 kWh; 250 lb.
Provides additional power for acceleration.

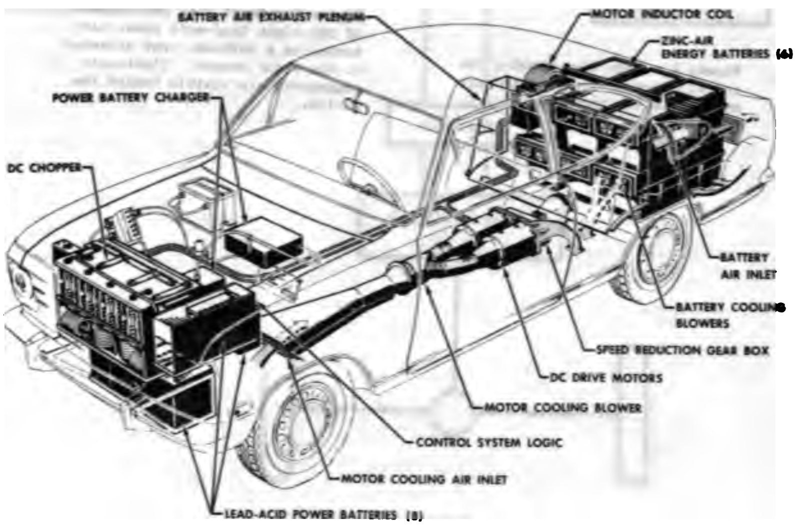
Motor - 2 - dc series motor (Delco-Remy)
14 HP continuous; 18.5 HP peak.

Controls - Solid state chopper and logic (GMR)

*Zinc-Air discussions were conducted with Leesona Moos Laboratories. Leesona Moos proposed to develop and build the zinc-air battery, but GMR decided to do the job in-house and gain important experience.

Performance:

	XEP-1A (1968 Opel Kadette)	1968 Opel Kadette
Curb Weight -	2957 lb	1720 lb
Test Weight -	3404 lb	
Power Train Weight -	1575 lb	425 lb
Battery Weight -	904 lb	
0-30 mph	8.5 sec	
Range: 30 mph	155 miles	
55 mph	90 miles	



X E P - 1 A

(GM Research)

Features:	ADVANTAGES	DISADVANTAGES
	Satisfactory urban range	Heavy
	No exhaust emissions	Cost premium
	Quiet operation	Long recharge time needed
	Potential promising Zn-air battery economics	Short life

Conclusion: Program stopped January 1971. Efforts directed toward research activity to evolve an electrically rechargeable zinc-air battery.

Figure 4 - Rear view showing the installation of the six zinc-air modules in the trunk of the vehicle.

Figure 3 - Front view showing four of the eight lead-acid power batteries on a pull-out tray attached to the front bumper. Electronic components are visible behind the grille.

W H I S P E R Y E T

(GMC Truck and Coach)

Program Started - mid-1968:

Shown November 1969; results presented to DOT personnel.

Power Train:

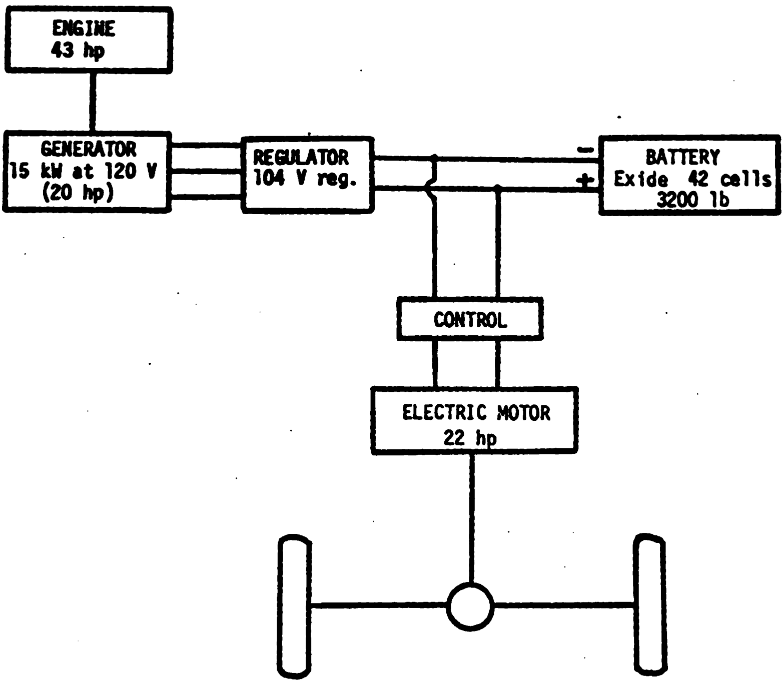
Series Hybrid -
- **Kohler engine-generator - 15 kW at 120 V**
- **Exide batteries - 3200 lb**
- **Electric Motor - DC traction - 20 HP - 80 V. (Purchased from Reliance Electric Company.)**

Test Bed:

City Bus - **GVW = ~20,000 lb; 25-30 passengers.**

Performance:

Top Speed - 27 mph.



W H I S P E R Y E T

(GMC Truck and Coach)

Conclusion: **Program stopped summer 1970; lack of promise.**

General Motors
Research Laboratories

GM STIR-LEC II

A STIRLING-ELECTRIC HYBRID CAR

Stir-Lec II is a second-generation hybrid automobile combining a Stirling external combustion engine with an electric drive system. It was developed by General Motors Research Laboratories as a test vehicle to explore the use of a low emission engine and an electric drive system in a small car.

The hybrid arrangement allows the use of a very small engine (eight horsepower) to provide electrical power for moderate constant-speed driving, with reserve power stored in a bank of batteries.

General Features

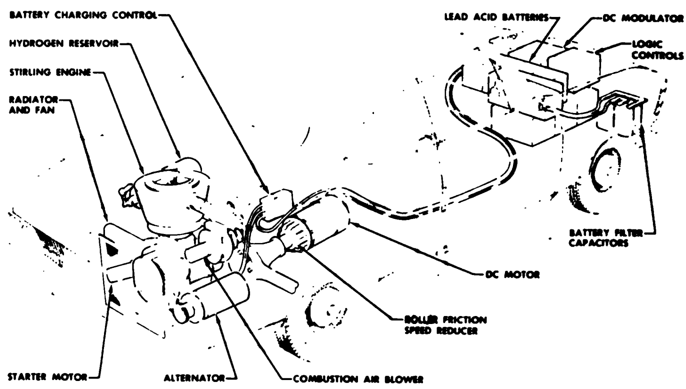
The first experimental vehicle of this family, Stir-Lec I, was introduced to the public in May 1968. The second, Stir-Lec II, features a more efficient electric drive system which provides the same power with simpler, more compact electronics. It is the latest result of an extensive development program on high-performance electric drive systems, coupled with over a decade of Stirling engine development.

Features of the Stirling engine include low exhaust emissions (considerably below both present and proposed government limits), quiet operation, and high efficiency. The electric system provides high peak power for rapid vehicle acceleration, the flexibility and performance characteristics of an electrical transmission, and zero exhaust emissions when the vehicle operates on batteries alone.

In Stir-Lec II, the small Stirling engine drives an alternator to charge the batteries. The battery output is electronically modulated to provide the necessary power variations for motor speed control. A 20-hp dc motor drives the vehicle through a GMR-developed roller friction speed reducer and the standard differential. This differs from Stir-Lec I which used an ac motor and speed reduction gears. In this small vehicle (a modified Opel Kadett) the advantages of simpler, less bulky dc system electronics outweigh the advantages of a smaller, lighter ac motor. In larger vehicles -- where a powerplant of more than 30-40 hp is required -- the large size and weight of the dc motor make the ac system more desirable. The GMR Electric Propulsion Department continues development of both systems for a variety of applications.

Low Emissions

In the Stir-Lec installations, the eight horsepower single-cylinder Stirling engine runs at constant speed. Although its main function is



charging the batteries, it also provides hot water for the car's heater. A diesel fuel burner supplies the required heat to the Stirling external combustion engine. Combustion characteristics are excellent. The engine package emits virtually no odor and very low amounts of carbon monoxide and smog-forming hydrocarbons. Carbon monoxide is typically about 0.3 grams per mile (gpm); proposed 1970 federal standards limit such emission to 23 gpm. Exhaust hydrocarbons are typically about 0.006 gpm; the proposed federal hydrocarbon limit is 2.3 gpm. The emission of oxides of nitrogen is about one gpm. The Stirling engine also is significantly quieter than conventional engines. This engine is a modified version of the Stirling developed by the GMR Mechanical Development Department for use in a silent portable Army generator (Ground Power Unit).

R&D . . . Test Results

The Stir-Lec cars were designed to explore the characteristics of this type of powerplant and drive system in a small standard car. The space required by the system (it uses all the engine compartment and trunk space), the added weight, and high cost all make this hybrid design commercially impractical at this time. However, Stir-Lec II does serve as a valuable test bed for continuing research and development.

Stir-Lec II features compact solid state chopper and logic controls for dc drive system.

Stir-Lec II has a top speed capability of about 60 mph, however the nominal operating speed is 30 mph. At 30, on a level road, the electric drive system draws energy from the batteries at about the same rate that the Stirling engine charges them. Thus the batteries essentially "float" on the system, and the Stirling supplies the required energy. At higher speeds, or for other temporary additional power needs (such as acceleration or hill climbing), the motor draws some of the stored energy from the batteries. The batteries can then be recharged during lighter-load operation.

The car also can operate with no emissions, with the Stirling engine shut down and the vehicle running only on the batteries. The emission-free range is about 30 miles.

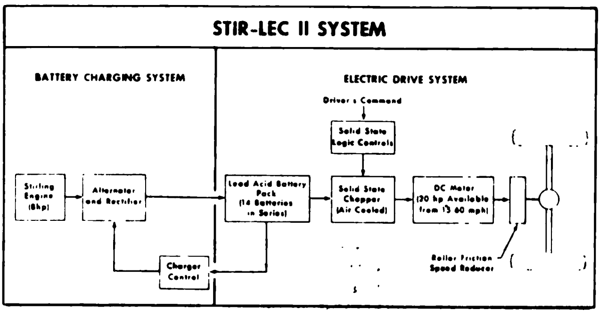
Initial performance data for Stir-Lec II looks like this:

Acceleration 0 to 30 mph, in 8.5 seconds.

Top speed, 60 mph.

Range, 25 miles at 30 mph on batteries alone.
150 miles at 30 mph with the charging system running (limited only by capacity of 5 gal. fuel tank).

The weight of the vehicle, including two occupants, is about 3250 pounds.



ATTACHMENT C

TABLE I.—*Consumer energy costs, Detroit area, February 1975*

	Per million Btu's
Natural gas	[1] $1.15
Gasoline	[2] 4.40
Electricity	[3] 8.26

[1] Monthly service charge of $3 per customer not included.
[2] At 55 cents per gallon.
[3] Monthly service charge of $2.40 per customer not included.

TABLE II.—ELECTRIC UTILITIES

GENERATION BY ENERGY SOURCE (PERCENT)

			1974 [3]—Fossil fuel only			
	1973 [1]	1974 [2]	United States	New England	West south central	East south central
Coal	45.8	45.5	57.1	13.1	3.2	92.5
Oil	16.8	15.2	20.6	85.4	6.8	4.1
Gas	18.2	17.7	22.3	15.0	90.1	3.4
Fossil total			100.0	100.0	100.0	100.0
Hydro	14.7	16.0				
Nuclear	4.5	5.6				
Total	100.0	100.0				

[1] Edison Electric Institute "Statistical Yearbook for 1973."
[2] Monthly Energy Review FEA, March 1975.
[3] FPC News, Mar. 28, 1975.

ATTACHMENT D

(Research Publication GMR-1798)

ENERGY UTILIZATION COMPARISON OF GASOLINE AND BATTERY-ELECTRIC POWERED URBAN VEHICLES

(By David C. Sheridan, John J. Bush, William R. Kuziak, Jr.)

ABSTRACT

An analytic study was conducted to compare the efficiency of utilization of the earth's fossil energy resources (petroleum and coal) by battery-electric and gasoline powered special-purpose vehicles. This report presents a brief overview of the study objectives, procedures and findings.

OBJECT

To present a brief review of the energy utilization comparison of gasoline and battery-electric powered urban vehicles.

SUMMARY

Assuming coal is the prime energy source, the energy consumption of a lead-acid battery electric powered 2-passenger shopper vehicle ranges from 25 percent less to about the same as that of a spark ignition engine powered vehicle that has similar performance and carrying capacity. With petroleum as the prime source of energy, the same battery-electric powered vehicle consumes over 40 percent to nearly 90 percent more than a conventionally powered vehicle over a prescribed driving cycle. Increases in desired range, performance or vehicle size beyond that of the shopper increase the electric vehicle energy consumption with respect to the gasoline powered version. These conclusions are based on current level technology. Battery technology advances enabling nickel-zinc cells to be utilized will improve the energy consumption of the electric vehicle with re ct to the gasoline powered vehicle by as little as 10 percent in the 40 km ra, 2-passenger shopper vehicle considered in this study and by as much as 40 in the 120 km range, 4-passenger sedan.

DISCUSSION

Introduction

In order to convey the important findings of an urban vehicle energy utilization study a brief overview of the objectives, procedures and findings has been prepared. An important aspect of this study is the basic guidelines set down at its onset. The more important ones are listed below:

1. Current technology supported by experimental data should be utilized to characterize the vehicle-powertrain systems.
2. The vehicles would be smaller and have substantially lower performance levels than those of conventional sub-compact cars.
3. The performance levels and load carrying capacity of the gasoline powered and battery-electric powered vehicles should be identical.
4. Energy consumption and driving range should be determined for operation over an appropriate driving cycle.

Vehicle definition

Three special purpose vehicles were selected for the study. The curb masses listed below apply to the gasoline powered versions and are based on prototypes built for the General Motors Progress of Power Show of May 1969.

2 passenger shopper—426 kg.
2 passenger commuter—544 kg.
4 passenger sedan—817 kg.

The mass of the electric powered versions was increased to account for the batteries and the additional vehicle structure (compounding effect) required for their support. Although these vehicles do not satisfy Motor Vehicle Safety Standards, changes required to conform to these standards will result in similar mass increases for both the electric and gasoline powered versions.

The performance was determined assuming an additional mass (occupants and cargo) of 136 kg. for the shopper and commuter and 204 kg. for the sedan.

The performance criteria established for each of the 3 vehicle types are listed in Table I. The performance of a Chevrolet Vega is shown for comparison.

TABLE I.—VEHICLE PERFORMANCE CRITERIA

Criteria	Shopper	Commuter	Sedan	Vega
Maximum car speed, km/h:				
2 percent grade, 24 km/h headwind		72	72	
0 percent grade, 0 km/h headwind	72	>97	>97	>125
Distance in 4 seconds, m	15			23
Distance in 10 seconds, m		91	91	122
0–48 km/h time, sec	20			6
0–72 km/h time, sec		30	30	12
5 percent grade speed, km/h	24	24	24	
20 percent grade speed, km/h	>0	>0	>0	
Electrical vehicle range, km	40	80	120	
Duty cycle, GMPG	(1)	(2)	(2)	

[1] Central business district.
[2] Suburban.

Engine size was selected to provide the maximum vehicle speed. A 3 or 4 speed synchromesh transmission was incorporated in both gasoline and battery powered vehicles to give the necessary torque multiplication for acceleration and grade performance. An electric motor could be designed to provide the desired level of vehicle performance at the expense of weight and efficiency. However available motor data dictated the use of the transmission.

Powertrain definition

The electric motor performance was based on data obtained from a 15 kW series-wound DC motor with a chopper control specially designed for vehicular application. The peak efficiency of this motor and controller was 78 percent. During the course of the study this performance was scaled from the 15 kW level to as low as 7 and as high as 45 kW. In addition, the effect of an increase in overall efficiency of 5 percent which could result from improvements to the electrical components was considered.

The spark-ignition engine (SI) characteristics were based on the measured performance of a 4-cylinder 1.2 liter Opel engine. The maximum output of this engine is about 42 kW. Its output was scaled at the same efficiency level, to as

low as 7kW. Scaling to 21 kW or half the 4 cylinder Opel rating is acceptable, as a 2 cylinder version would provide such performance. Scaling another 67 percent to 7 kW leaves room for considerable debate as to the validity of maintaining the same efficiency level. Therefore, the effect of a 20% increase in part-load fuel consumption was investigated.

The remaining portions of the powertrain including synchromesh transmission, rear axle, clutch, etc., were characterized on the basis of current, experimentally determined information.

An essential consideration for any marketable automobile is the accessory requirements. A minimum load of 250 watts at a vehicle speed of 48 km/h to provide for lighting, ventilation and radio was estimated. The addition of an auxiliary passenger heater would be necessary for the electric powered vehicle and quite possibly for the smallest gasoline powered versions, increasing the total accessory load an order of magnitude to 2500 watts. Optional air conditioning would require about the same amount of power. However, for the purposes of this study the minimum accessory load (250 watts) was used. The electric vehicle accessories were assumed to be a constant load powered by the main battery pack. The gasoline powered vehicle accessories were belt driven in the conventional manner.

The vehicle road load characteristics were determined using coefficients for wind resistance and rolling resistance determined experimentally for a Honda Civic. Vehicle frontal area was assumed to be 1.67 m^2 for the shopper, and 1.86 m^2 for the commuter and the small sedan. The assumption of identical frontal areas does not account for potentially larger values for the electric version due to the large battery volume required. However, the relatively low speed driving cycles being considered in the study justify the assumption.

A critical assumption for the electric vehicle is the amount of added mass required to support the batteries. For the purposes of this study, two compounding factors were considered, 50 percent and 30 percent. In other words, for every 110 kg of battery required an additional 50 kg or 30 kg of structure must be added to the vehicle.

Battery characterization

The most important component in the electric vehicle system, the battery, is also the most difficult to model. The primary study was carried out using experimentally determined energy-density and power-density characteristics for a Delco-Remy lead-acid battery developed in the late 1960's for an electric vehicle prototype.

The energy available from a battery is dependent on several factors: (1) the rate or rates at which it is discharged, (2) its operating temperature and (3) age of the battery. The assumptions were made that the battery was new and operating at 294 K (70 F). Also, it was assumed that the amount of energy in kilowatt hours (kW-h) available from the battery for driving cycle operation at various power levels was equal to the energy available from the battery if it had been drained only at the maximum level demanded by the motor. When the available energy was withdrawn, the next vehicle maneuver requiring maximum power would result in the battery terminal voltage dropping below a specified level. The distance travelled by the vehicle prior to this instant was defined as its range.

It is recognized that assuming the quantity of energy available over a duty cycle that demands a range of power levels is identical to the quantity available if it is drawn only at the maximum level of the cycle will result in underestimates of range. However, parallel calculations using measured constant-current voltage-time characteristics to more accurately determine the energy availability produced range increases of only 5 percent. It is also noteworthy that considerable energy is left in the battery, i.e., 40 to 50 percent, at the point where vehicle range is determined by the driving cycle performance demands. If the remaining energy is withdrawn at reduced power levels more range is available.

Another subject concerning the available range of lead-acid battery-powered vehicles is charge recuperation. Left in the open circuit condition for several minutes, the charge level of a battery will rise. Driving habits that result in idle or stop time that is substantially longer than driving time will result in range increases if vehicle cold start effects do not become a significant counteracting influence. The recuperative effects of such idle periods were not considered in this study.

Regenerative braking as a means of increasing vehicle range was not considered in the study. Lead-acid batteries are not aptly suited for high charging

rates which would be encountered. Furthermore, it is the concensus of most investigators that a range increase of less than 10 percent would be realized.

The efficiency of charging and discharging the batteries requires some additional assumptions. Charging lead acid batteries to the 110 percent level is recommended to guarantee a full charge. If it is done over an 8 hour period with a charger that varies current linearly with time, calculations indicate that 28 percent more energy must be added than can be withdrawn from a full charge to any charge level. In other words, a charge-discharge efficiency of 78 percent is typical of lead-acid batteries. A charging-device efficiency of 90 percent is anticipated for home-type chargers. The overall charge-discharge efficiency is thus 70 percent.

The study was extended to include nickel-zinc batteries, currently the most advanced batteries practically adaptable to vehicular application. Actual experimental performance was used to model this type battery as well. Energy densities 1 to 3 times greater than that available from the high energy lead-acid battery characterize this particular nickel-zinc cell. The same overall charge-discharge efficiency of 70 percent was used when determining the vehicular energy consumption.

Energy production and distribution

To evaluate and compare the utilization of the Earth's prime energy sources by gasoline and battery electric powered vehicles, the efficiency of producing electricity and gasoline from these prime sources must be considered. Coal and petroleum are the only sources considered in this study even though nuclear fuel is potentially the greatest source of our future energy supply. The magnitude of the radioactive reserves needed for nuclear power generation are not known and a comparison with the utilization of coal or petroleum would be meaningless.

The production and distribution efficiencies of gasoline available at a retail pump and electricity available from an AC outlet in the home, from coal and petroleum as prime sources are illustrated in Fig. 1. These efficiency levels are representative of present-day processes and operations.

Vehicle energy utilization

A summary of the energy utilization study is presented in Figures 2 through 5. Figure 2 shows electric-vehicle range in kilometers as a function of mass on the appropriate vehicle driving cycle. Both lead-acid and nickel-zinc batteries are considered. The range for each of the 3 vehicle types is shown as a band. The top of the band represents a 30 percent mass "compounding" effect, the bottom a 50 percent effect. No recuperative effects or operation at performance levels less than those required by the driving cycles were considered.

Equivalent prime-source energy consumption in terms of megajoules per kilometer of driving over the prescribed cycle is plotted as a function of total vehicle mass in kilograms in Figures 3 and 4. The data of Figure 3 assumes petroleum as the prime source, and Figure 4 is based on coal. Energy consumption of the 3 battery-electrics are shown as bands, each increasing with vehicle mass. The top of each band was determined for current electrical component efficiency data. The bottom of each band represents an overall efficiency improvement of 5 percent.

From Figure 2, the vehicle mass corresponding to the desired range available from lead-acid batteries was determined, i.e., 40 km for the shopper; 80 km for commuter and 120 km for the sedan. This vehicle mass "spread" (resulting from the different "compounding" assumptions) is indicated in Figures 3 and 4 as a darkened parallelogram for each vehicle type. The maximum and minimum values defined by these small areas defines the variation in energy consumption of each vehicle type referred to the prime source of energy. The maximum value corresponds to current electrical component efficiency levels and a mass compounding factor of 50 percent. The minimum value represents a 5% increase in electrical component efficiency and a 30% compounding factor.

Also shown in Figures 3 and 4 are the equivalent energy consumptions determined for the gasoline-fueled, spark-ignition-engine versions of the three urban vehicles. These energy consumptions are shown as vertical bands illustrating a possible 20 percent decrease in operating efficiency from the level of the 1.2 liter engine used in the study to that of an engine with ½ to ⅛ that displacement Also spotted on these figures is the energy consumption of three 1974 Chevrolet automobiles, i.e., an 8-cylinder Impala, a 6-cylinder Nova and a 4-cylinder Vega. As a point of reference these values represent measured Suburban driving cycle fuel economies of 10.9, 14.0 and 20.3 miles per gallon.

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In Table II below, a comparison is made of the energy consumption of lead-acid battery-electric and gasoline powered vehicles with the same cargo capacity and performance. The maximum ratios represent the assumption of a 50% mass compounding "factor" and currently available powertrain efficiency levels for the electric vehicle. Increasing the fuel consumption of the spark ignition engined vehicles 20% to account for the small engine size coupled with the 5 percent electrical component improvement and the lower mass compounding factor of 30 percent for the electric vehicles results in the minimum ratios.

TABLE II.—ENERGY CONSUMPTION RATIO: LEAD-ACID EV/SI

	Petroleum	Coal
Shopper	1.88-1.42	.97- .73
Commuter	2.44-1.72	1.26- .89
Sedan	3.41-2.22	1.76-1.14

Effect of advanced battery application

Assuming nickel-zinc batteries can be used in place of the lead-acid type, the vehicle mass corresponding to the desired range is considerably reduced as indicated by Figure 2. Extrapolating the equivalent energy consumption bands in Figure 3 to sufficiently low levels for each vehicle type, the effect of utilizing these higher energy batteries was determined. These effects are shown in Table III below where the nickel-zinc battery-electric vehicle energy consumption is compared with that of the spark ignition engine powered vehicle.

TABLE III.—ENERGY CONSUMPTION RATIO: NICKEL-ZINC EV/SI

	Petroleum	Coal
Shopper	1.65-1.28	.85- .66
Commuter	1.79-1.36	.92- .70
Sedan	2.00-1.48	1.03- .76

In Figure 5, a summary of the calculated energy consumption from both prime sources (coal and petroleum) for the three types of vehicles powered by electricity or gasoline are shown. The ranges of energy consumption values reflect the variation of the mass "compounding" effect and the powertrain efficiency levels assumed in the study.

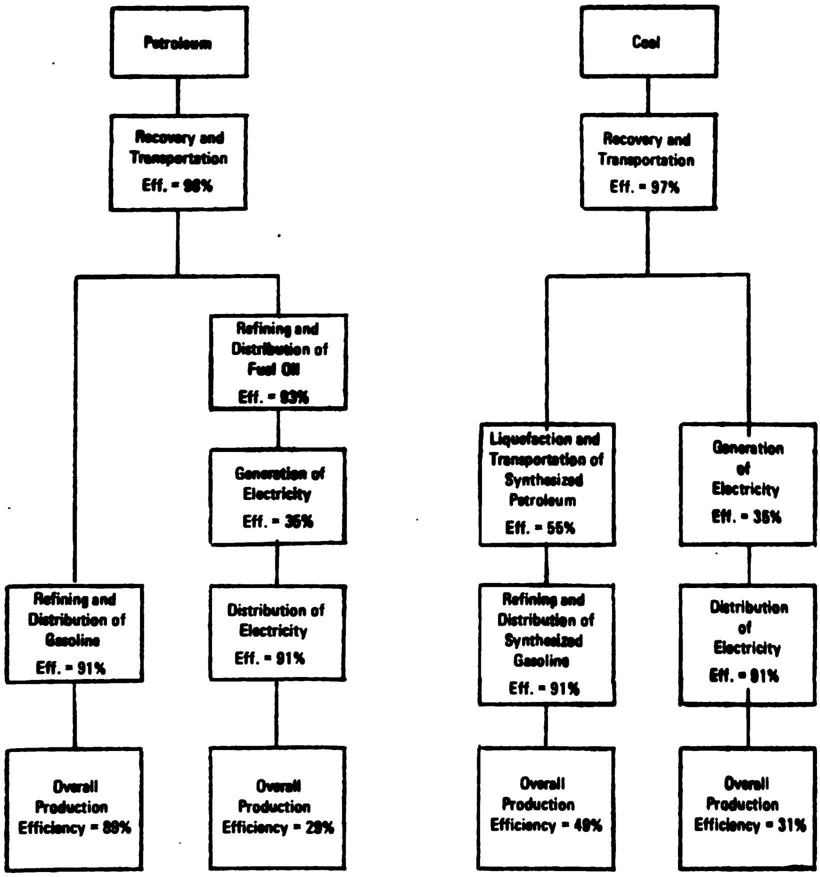
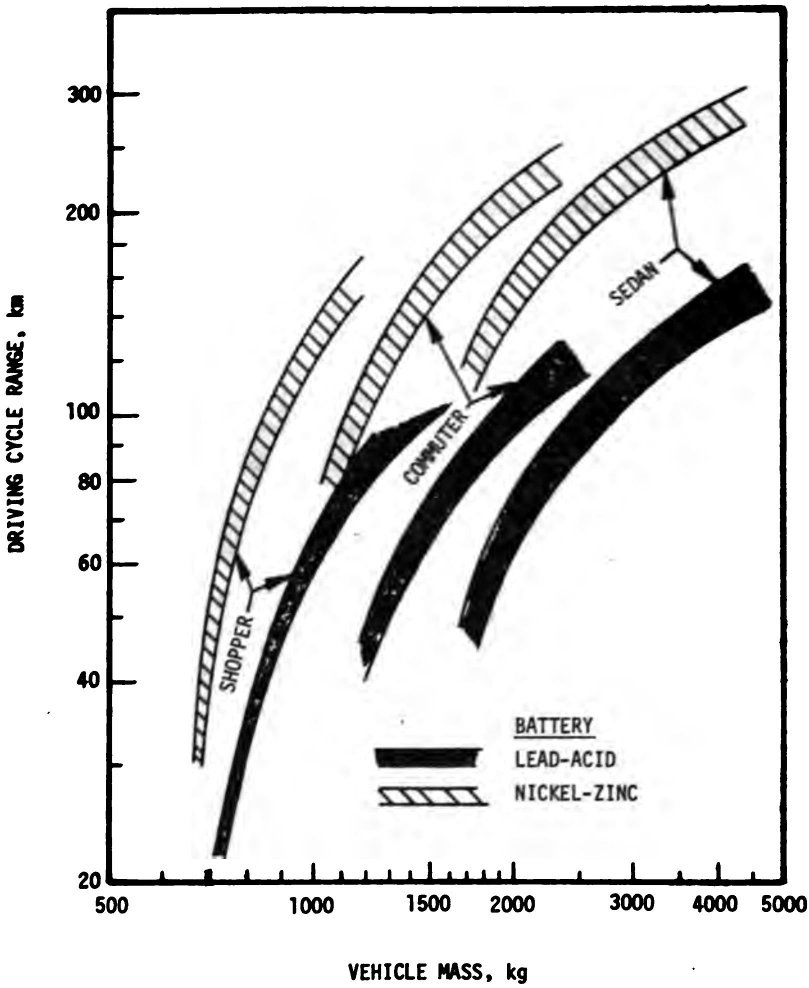

Petroleum
Recovery and Transportation Eff. = 98%
Refining and Distribution of Fuel Oil Eff. = 93%
Generation of Electricity Eff. = 35%
Refining and Distribution of Gasoline Eff. = 91%
Distribution of Electricity Eff. = 91%
Overall Production Efficiency = 89%
Overall Production Efficiency = 29%
Coal
Recovery and Transportation Eff. = 97%
Liquefaction and Transportation of Synthesized Petroleum Eff. = 55%
Generation of Electricity Eff. = 35%
Refining and Distribution of Synthesized Gasoline Eff. = 91%
Distribution of Electricity Eff. = 91%
Overall Production Efficiency = 49%
Overall Production Efficiency = 31%

FIGURE 1



DRIVING CYCLE RANGE, km
300
200
100
80
60
40
20
500
1000
1500
2000
3000
4000
5000
VEHICLE MASS, kg
SHOPPER
COMMUTER
SEDAN
BATTERY
LEAD-ACID
NICKEL-ZINC

FIGURE 2

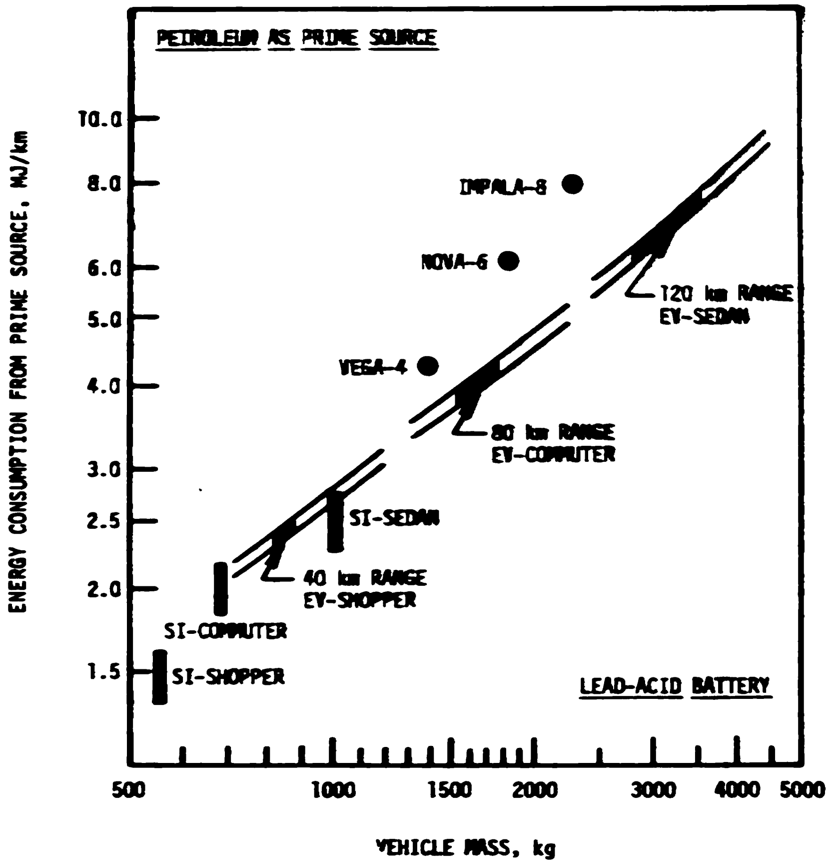

PETROLEUM AS PRIME SOURCE
ENERGY CONSUMPTION FROM PRIME SOURCE, MJ/km
10.0
8.0
6.0
5.0
4.0
3.0
2.5
2.0
1.5
IMPALA-8
NOVA-6
VEGA-4
120 km RANGE
EV-SEDAN
80 km RANGE
EV-COMMUTER
SI-SEDAN
40 km RANGE
EV-SHOPPER
SI-COMMUTER
SI-SHOPPER
LEAD-ACID BATTERY
500
1000
1500
2000
3000
4000
5000
VEHICLE MASS, kg

FIGURE 3

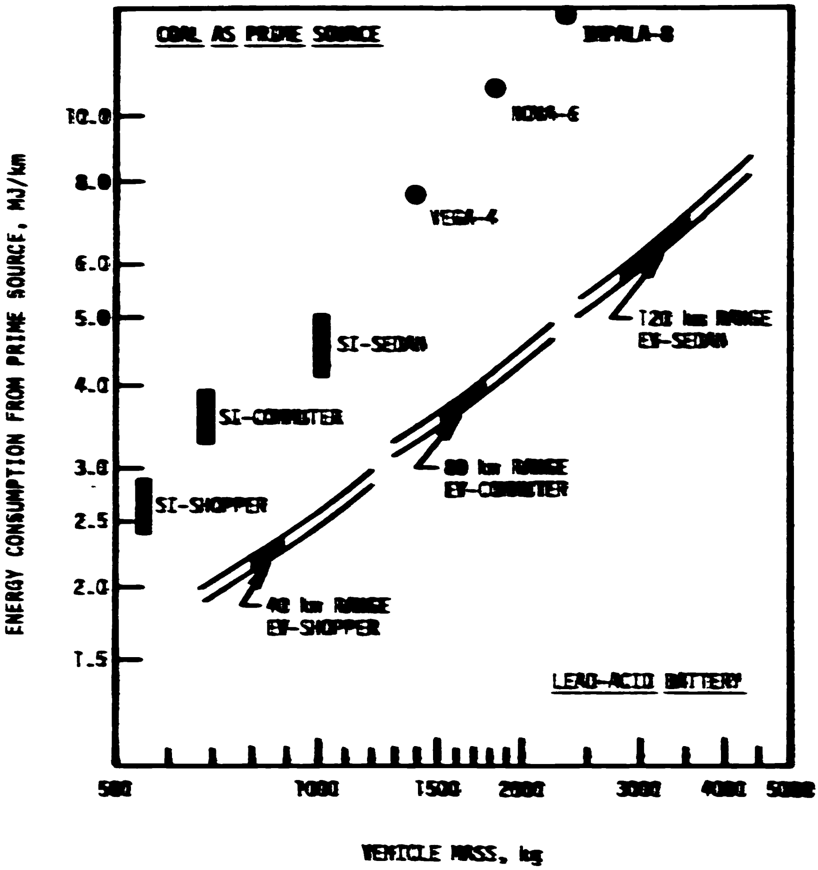
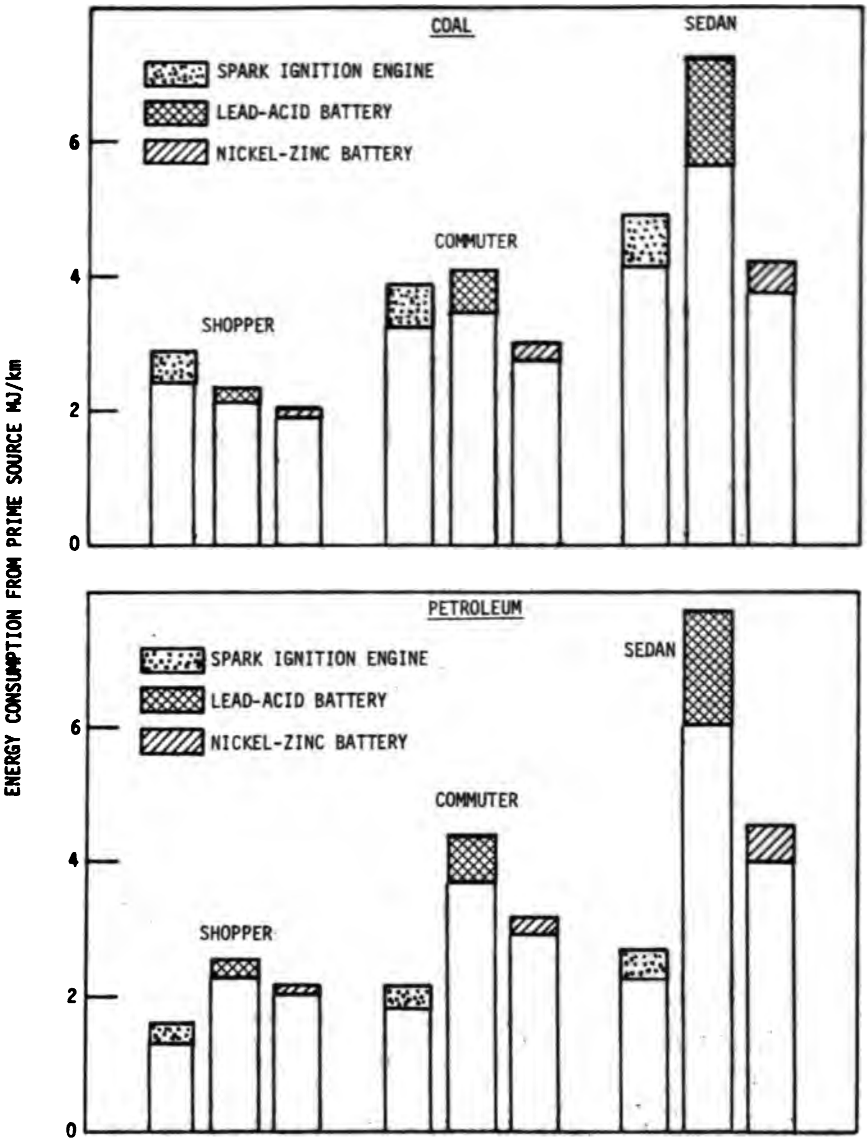

COAL AS PRIME SOURCE
IMPALA-8
NOVA-6
VEGA-4
SI-SEDAN
SI-COMMUTER
SI-SHOPPER
120 km RANGE
EV-SEDAN
80 km RANGE
EV-COMMUTER
40 km RANGE
EV-SHOPPER
LEAD-ACID BATTERY
10.0
8.0
6.0
5.0
4.0
3.0
2.5
2.0
1.5
500
1000
1500
2000
3000
4000
5000
ENERGY CONSUMPTION FROM PRIME SOURCE, MJ/km
VEHICLE MASS, kg

FIGURE 4



PRIME SOURCE ENERGY UTILIZATION
COMPARISON OF GASOLINE AND BATTERY-
ELECTRIC POWERED URBAN VEHICLES

FIGURE 5

ATTACHMENT E

POLLUTANT EMISSIONS IN GRAMS PER MILE OF TRAVEL IN LATE 1970'S

	I.C. engine automobile (EPA standards)		Electric car (EPA standards for new power plants) coal fired
	1976	1978	
Unburnt hydrocarbons	1.5	0.41	
Carbon monoxide	15	3.4	
Oxides of nitrogen	3.1	.4	2.53
Sulfur dioxide	[1] .11	[1] .11	4.35
Particulates	[1] .1	[1] .1	.36
Total mass	19.81	4.42	7.24
Health weighted equivalent based on primary national air quality standards	2.84	.56	6.53

[1] There are no standards presently proposed for SO_2 and particulate emissions. The SO_2 value is based on 0.03 percent sulfur content in gasoline, which is considered average. Particulate value is in agreement with a preliminary Federal proposal, and the 1976–78 emission control systems should meet this level with unleaded fuel.

Since the relative effect of the above pollutants on air quality differs widely, it is more meaningful to compare them on a health weighted equivalent basis using Primary Ambient Air Quality Standards established by EPA. The above data show that replacing an I.C. engine car by an electric car to transfer primary energy source from petroleum to coal would increase air pollution by a factor of 2.3 in 1976 and almost twelve times in 1978.

The electric car for which the above emissions were calculated matches the performance of a present-day compact automobile, including air conditioning, and assumed that high energy density batteries 100 watt-hours per pound would be available.

The emissions standard for coal fired plants would necessitate coal with 0.8% sulfur. Since the bulk of U.S. coal has over 2% sulfur, scrubbers which may add 20–30% to the cost of an electric power plant would be required.

ATTACHMENT F

IMPACTS OF ELECTRIC CAR USE IN ST. LOUIS, PHILADELPHIA, AND LOS ANGELES

William Hamilton

GENERAL RESEARCH CORPORATION

In June of 1973, under contract to EPA, General Research Corporation undertook an eighteen-month study of energy, environmental, and socioeconomic impacts of electric car use in the Los Angeles region. A second study, to be concluded in August, 1975, was begun a year later to analyze impacts in the St. Louis and Philadelphia regions. This discussion draws on both studies.

Key characteristics of the three regions under study are shown in Chart 1. They differ markedly not only in size, as the chart shows, but also in their relative dependence on coal, petroleum, and nuclear power, on their meteorological conditions, and on their historical dependence on the automobile. For the future, however, baseline projections made in the electric car studies show increasing similarity, especially in patterns of automobile use and growing dependence on nuclear electric power. Projected population growth rates for the three regions are roughly equal and are all under one percent per year.

CHART 1

STUDY REGIONS

	Area square miles	1970 Population (millions)	1970 Autos (millions)
St. Louis	4,100	2.4	0.9
Philadelphia	3,800	5.1	1.8
Los Angeles	8,700	9.7	5.1

Electric cars characterized originally in the Los Angeles study were used as a basis for the St. Louis and Philadelphia impact analyses. They utilized four representative battery technologies: high-performance lead-acid electric vehicle batteries, nickel-zinc alkaline batteries, zinc-chlorine batteries, and high-temperature molten salt batteries. A computer program was developed to model battery discharge while meeting power requirements of electric cars for urban driving. The SAE Metropolitan Area Driving Cycle for electric cars was used in this program; it calls for a stop each mile, an average speed of 24 mph, and an energy requirement per mile very near that of the Federal Driving Cycle.

After a parametric analysis, the specific car ranges of Chart 2 were selected for the impact analysis. The electric cars were efficient four-passenger subcompacts with performance slightly below that of current low-performance conventional subcompacts; they were capable of accelerating from 0 to 40 mph in 10 seconds, and of cruising on a freeway at 60 mph. At a constant 30 mph on a level road, car ranges would be over twice those shown for urban driving; in hilly terrain or near the end of battery life, however, they could be significantly less.

CHART 2

ELECTRIC CAR CHARACTERISTICS

Battery type	Lead-acid	Nickel-zinc	Zinc-chloride	Lithium-sulfur
Car weights (pounds)	3,975	3,530	2,950	2,575
Urban range (miles)	54	144	145	138
Battery weight (pounds)	1,500	1,090	570	3C0
Energy consumption (kilowatt-hour per mile)	.79	.51	.51	.45

Characteristics of batteries used in the electric cars are shown in Chart 3. The lifetimes shown assume urban driving of about 30 mi/day. For the lead-acid battery, the projected range of lifetimes is based on current experience; the longer life projection is optimistic. For the nickel-zinc and zinc-chlorine batteries, the indicated lifetimes assume that developers' goals for lifetimes of 400 and 500 deep discharges, respectively, will be achieved, and that life with partial discharges will be increased in inverse proportion to discharge depth. For the lithium-sulfur battery, which must be maintained at a very high temperature, the indicated lifetime range is assumed to be independent of use. Cost and life characteristics for the zinc-chlorine and lithium-sulfur batteries are relatively uncertain, and the figures in Chart 3 are quite optimistic.

CHART 3

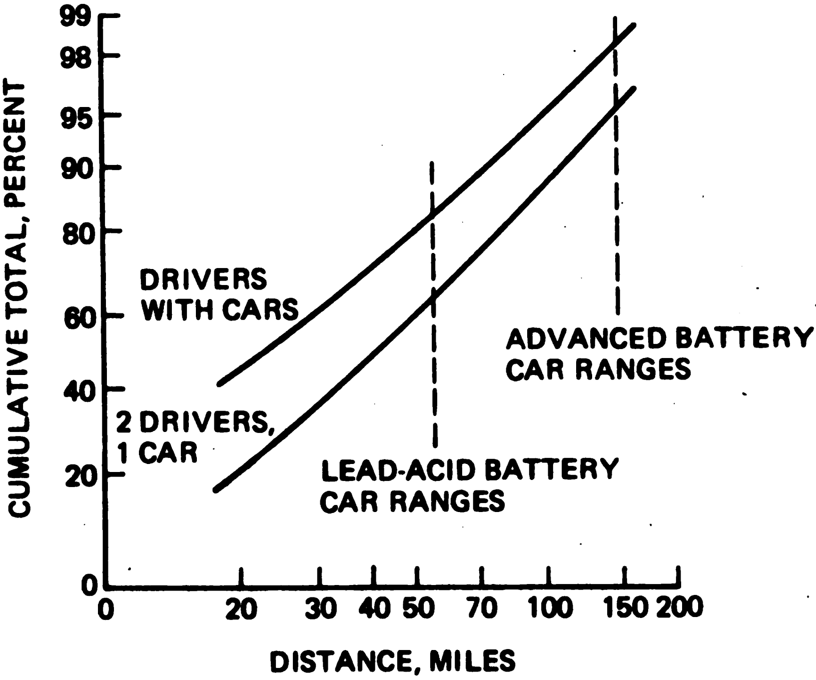
CAR BATTERY CHARACTERISTICS

Type	Lead-acid	Nickel-zinc	Zinc-chloride	Lithium-sulfur
Weight (pounds)	1,500	1,090	570	300
Available energy, kilowatt-hour per pound	13	44	70	140
Energy efficiency (percent)	46	66	70	62
Life (years)	1.3-3.4	5.8	7.3	3-5
Cost, 1973 dollars	$1,200	$4,380	$600	$600

The electric car ranges of Chart 2 were selected after a new analysis of Los Angeles travel data which had been collected in an extensive 1967 survey. Chart 4 shows the resultant distribution of driving distances on the survey day for drivers with cars exclusively available to them, and for drivers sharing a single car. In all three regions, high auto ownership rates are projected so most drivers will have cars exclusively available. Furthermore, daily annual auto usages in the three regions are approximately equal, and are increasing rather slowly. Chart 4 reveals that the cars of Chart 2 with 145-mile range would be inadequate on only 2% of urban driving days. The car with 54-mile range, however, would be inadequate on about 1 driving day out of 6, a frequency considered unacceptable. As a secondary car in a two-car household, however, where longer trips were accomplished by the primary car, 54-mile range could be adequate on over 97% of driving days. Roughly one out of six cars will be in this category by 1980.

CHART 4

DISTRIBUTION OF SURVEY DRIVER TRAVEL

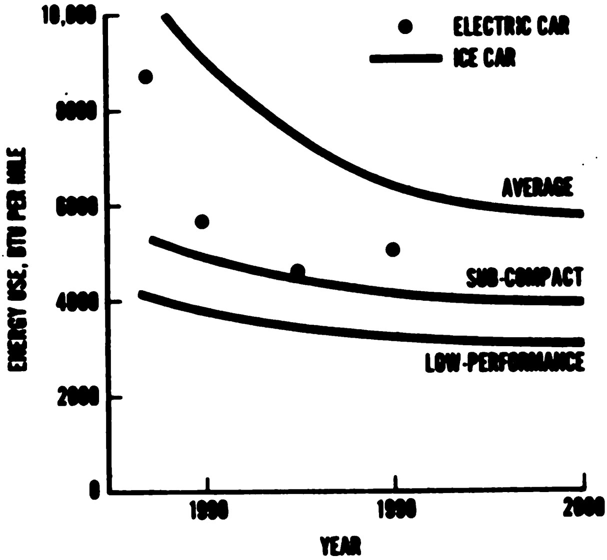


The energy use of electric and conventional cars is projected and compared in Chart 5. Here the electric cars are those described in Chart 2. Their energy use per mile is expressed in terms of heat energy required to operate the electric power station providing recharge power. Average generation efficiency of 36% and distribution efficiency of 92% are assumed.

The energy use of the average ICE car in Chart 5 improves substantially in the future, partly because of a projected continuing shift to smaller cars, partly because of a projected improvement in efficiency of energy use for each size class of car. These projections are, in the longer term, compatible with Federal legislation under development in 1973–74 and with the DOT–EPA report to Congress on automotive energy consumption.

CHART 5

COMPARATIVE ENERGY USE



Despite the major improvement in Chart 5 projected for the average ICE car, the electric cars would require less energy per mile. This comparison, however, is not entirely fair, because the average ICE car is both larger and more powerful than the electric subcompact of Chart 1. Accordingly, Chart 5 also shows projected energy use for ICE subcompacts comparable in size to the electric cars, both with performance typical of current US subcompacts and with low performance like that of the electric cars. In comparison with these subcompacts, the electric cars use considerably more energy. This is largely attributable to their much greater weight. The lead-acid battery car, for example, weighs over 60% more than the typical subcompact, and requires additional energy per mile in almost the same proportion.

In Los Angeles, where a very mild climate prevails, waste heat from the electric motor and controller is sufficient for winter temperature control and air conditioning is not essential in the summertime. In St. Louis and Philadelphia, however, which are both colder in winter and hotter in summer than Los Angeles, both supplementary winter heating and summer air conditioning are necessary. Additional energy requirements estimated for this purpose are shown in Chart 6 as a percentage of the recharge energy required for average daily driving of thirty miles. Supplemental heating in the peak month, January, increases energy use over that for propulsion alone by ten to thirteen percent, depending on battery type in the electric car. Over the full year, average extra energy use for heating would be much less, of course. To minimize withdrawal of energy from the propulsion battery, pre-heating of the electric car directly

from the power line before its daily usage begins is desirable. Estimated preheat requirements are accordingly included in Chart 6.

Air conditioning requirements estimated in Chart 6 assume a 2.3 kW cooling capacity, adequate for maintaining interior comfort in ambient temperatures over 100° F. Peak-month utilization would be higher in St. Louis than Philadelphia owing to substantially higher average daily maximum temperatures. Over the full year, average cooling energy requirements are estimated to be on the order of those for supplemental heating and pre-heating.

CHART 6

ADDITIONAL ENERGY FOR TEMPERATURE CONTROL

[Percent of basic recharge energy]

	St. Louis	Philadelphia
Supplemental heat:		
January	10 to 13	10 to 13.
Full year	2.4 to 3.1	2.6 to 3.4.
Preheat:		
January	9 to 18	9 to 18.
Full year	3.8 to 6.8	3.8 to 6.8.
Cooling:		
August	15 to 20	11 to 14.
Full year	3.4 to 4.4	2.4 to 3.1.

After allowance for the minority of electric cars which would probably not be equipped with air conditioners, plus a reduction in preheating requirements for electric cars parked overnight in garages rather than outdoors, average overall energy requirements for temperature control are estimated at six to ten percent of recharge energy for propulsion alone.

Under maximum heating or maximum cooling requirements, electric car range would be reduced by about sixteen percent for all battery types. Since maximum ranges are much greater than driving requirements for most days, as shown in Chart 4, the overall result would be that drivers would have to choose between comfort and driving range on only a few percent of driving days.

Growth in per capita electric power demand was projected at 4½% per year for all three regions, a conservative rate relative to past experience. Hourly demand profiles were individually forecast for the regions for representative days during the full year, and then matched with forecasts of projected supply by energy sources. A typical result is shown in Chart 7.

Chart 7 shows the level of load, as a percent of the annual peak, which is exceeded during different fractions of the year. The lower curve on the chart is the baseline forecast for the case of zero electric car use. Also shown are the effects of recharging electric cars when they are used to replace 20% and 80% of conventional cars in the region. As Chart 7 shows, nuclear power stations are planned to meet the base load in St. Louis in 1990. They would operate whether or not electric cars were being recharged. The next cheapest source, coal, would be used to meet most of the variations in demand level, and consequently would supply most of the recharge power for electric cars. A relatively small portion of annual electric energy supply, required only during peak periods, would be met from a number of other sources, including hydroelectric plants, pumped storage, oil-fired steam plants, combustion turbines, and purchases from other regions. Only the last three of these power sources involve petroleum fuels. As the chart shows, even at 80% electric car use almost no recharge energy would be required from these sources. Similar charts for Philadelphia and Los Angeles would show increasing reliance in both regions on petroleum, with the result that electric car use would be much more dependent on petroleum fuel.

CHART 7

ELECTRIC UTILITY LOAD-DURATION PROFILE

ST LOUIS, 1990

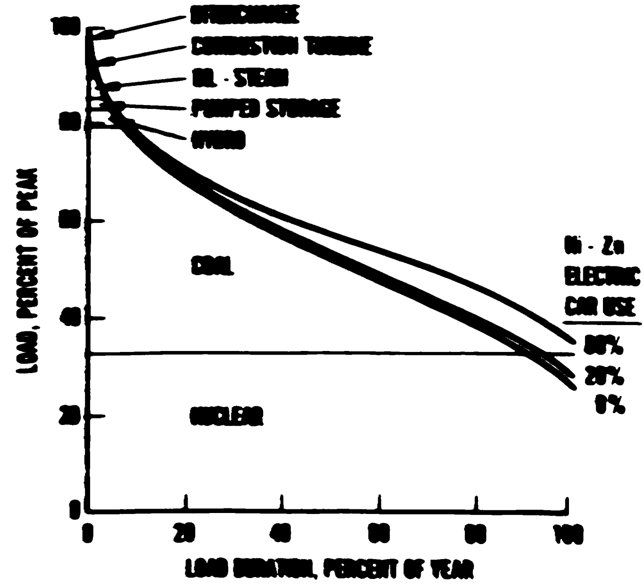


Chart 8 shows estimated 1990 petroleum use in the three regions as a function of electric car usage. Evidently potential petroleum savings with electric car use are greatest in St. Louis and least in Los Angeles. For each region, a band of possibilities is shown corresponding to the type of cars assumed to be replaced by electric cars. The lower boundary, corresponding to minimum petroleum saving, would result if electric cars replaced subcompacts first, then larger cars in order of size. At 100% electric car usage, only average cars can be replaced, of course; but in 1990, sufficient recharge power will not be available for 100% electric car use on peak-demand days.

CHART 8

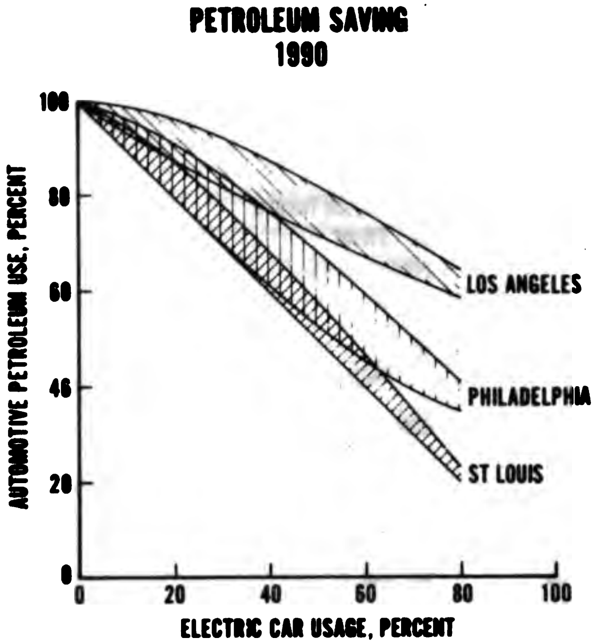


Chart 9 shows projected regional emissions of air pollutants in 1990 as a percentage of annual emissions in the early 70's. In these reference years, all three study regions exceeded air quality standards for oxidant concentrations, largely as a consequence of high hydrocarbon (HC) emissions, and also exceeded carbon monoxide standards. Automotive emissions were major factors in both these pollution problems. So_x levels also exceeded air quality standards; here electric power plant emissions were the major factor, with autos contributing very little. In the projections of Chart 9, future emission from stationary sources were assumed to comply with local regulations, which in turn generally follow Federal regulations. For vehicular sources, emissions in St. Louis and Philadelphia were assumed to comply with the delayed schedule of emission standards under the Clean Air Act of 1970 recently proposed to the Congress by EPA. These changes would delay imposition of the most stringent emissions levels from 1977 to 1982. In the Los Angeles projections, however, this delay was not assumed. It appears likely that nationally the delay will be adopted, but California has already requested a waiver of the delayed schedule in favor of that now in effect.

Chart 9

AIR POLLUTANT EMISSIONS

[Percent of 1970–72 average]

	1990	
	Baseline	80 percent electric cars
HC:		
St. Louis	44	37
Philadelphia	62	55
Los Angeles	19	16
CO:		
St. Louis	27	17
Philadelphia	28	18
Los Angeles	11	8
SO_x:		
St. Louis	72	85
Philadelphia	68	85
Los Angeles	158	180

In the 1990 baseline projection of Chart 9, there are substantial reductions in air pollutant emisions even in the absence of electric cars. For Los Anegeles, where no delay in stringent vehicular emissions control is assumed, the baseline changes in HC and CO are particularly dramatic. Additional projected reductions in Chart 9 due to very high usage of electric cars appear relatively modest in comparison. Because of the recharge power generation, SO_x emissions will be increased over the baseline by electric car use in all three regions. Use of stack gas scrubbers, which are not now implicit in the baseline projection, may make possible a major reduction in the level of SO_x emissions, both with and without electric cars.

For Los Angeles, the emissions reductions in the baseline projection of Chart 9 will dramatically improve air quality, but not quite to the stringent Federal standards. The additional modest changes due to electric car use will not make the difference between compliance and non-compliance. Air quality projections based on the emissions projections of Chart 9 have not yet been completed for St. Louis and Philadelphia.

Chart 10

1990 LIFE-CYCLE COSTS

[1974 cents per mile]

	Ice subcompact	Electric cars			
		Lead-acid	Nickel-Zinc	Zinc-Chlorine	Lithium-Sulfur
Depreciation:					
Vehicle	2.4	2.7	2.7	2.7	2.6
Battery	0	4.0–10.3	5.6	.9	1.3–2.2
Upkeep	2.5	1.5	1.2	1.2	1.2
Fuel	1.2	2.8	1.8	1.5	1.6
Pollution control	.9	0	0	0	0
Financing	1.6	2.9	4.1	2.4	2.4
Taxes, et cetera	4.3	4.5	4.5	4.5	4.5
Total	13	18–25	20	13	14–15

Comparative costs for conventional and electric cars are shown in Chart 10, Overall, as the bottom line shows, the nearer-term electric cars are expected to be much more expensive than their conventional counterparts, primarily because of battery depreciation. The range shown for the lead-acid electric car results from the range of possible battery lifetimes in Chart 2. Vehicle life is assumed to be 100,000 miles for the conventional subcompact and 120,000 miles for the electric cars. Fuel costs are forty cents per gallon for gasoline (not including tax) and 3.6 cents per kW for electricity. Costs in Chart 10 are averages for the three regions; the variation from region to region in total cost is less than a cent per mile. Costs of temperature control are not included; they range from .5 to 1.0 cents per mile for the electric cars. Despite the advantages of electric cars in reduced maintenance and pollution control, they are unlikely to approach the

conventional subcompact in overall economy until battery development drastically reduces battery depreciation costs.

CHART 11

EMPLOYMENT IMPACTS—100 PERCENT ELECTRIC CAR USE 1990

Region	Percent change in employment	
	Minimum	Maximum
St. Louis	−0.2	−1.1
Philadelphia	0	−.9
Los Angeles	−.2	−1.2

Impacts on employment of 100% usage of electric cars are shown in Chart 11. Depending on the type of electric car in use, they range from 0 to a little over 1%. Since these impacts would appear gradually over the considerable period of years required to build up substantial electric car usage, and in any case are much less than the average regional levels of unemployment, they must be considered small. Impacts in Philadelphia are generally less than in St. Louis and Los Angeles because most eliminated jobs are in gasoline filling stations, and Philadelphia has historically had fewer employees per automobile in these stations.

In summary, it may be concluded that the applicability of electric cars to urban driving is surprisingly high, even with lead-acid batteries. Potential energy savings due to electric car use are not large, but petroleum savings in 1990 and 2000 can be important where coal-fired and nuclear power plants provide recharge power. Air quality improvements due to electric car use are likely to be relatively modest owing to the major improvements in progress for conventional automobiles. Until battery depreciation costs are substantially reduced by advancing technology, electric cars will be at a substantial cost disadvantage relative to conventional subcompacts. Effects of electric car use on regional employment will be minor.

AM GENERAL CORPORATION,
Wayne, Mich., October 17, 1975.

Hon. FRANK E. MOSS,
Chairman, Subcommittee for Consumers Committee on Commerce, U.S. Senate, Washington, D.C.

DEAR SENATOR MOSS: I have been asked by Mr. Roy D. Chapin, Jr. to respond to your letter and questionnaire requesting comments on S. 1632. Our company is now producing electric vehicles, so we are very much interested in S. 1632 and appreciate the opportunity to comment.

There can be little doubt that we must find a suitable alternate source of power for internal combustion engine vehicles as soon as possible. The battery driven electric vehicle seems to give the greatest promise of providing an early solution.

In prior times we might have been able to leave the development of a replacement power source to natural market forces. The complexity of our present-day society and our great dependence on the automobile now make it imperative that we find the solution more quickly, which only can be done by the combined efforts of the federal government and industry.

We believe that the demonstration program can be effective with current state-of-the-art vehicles if they are placed in fleet operations whose operating profile is matched by the present-day vehicle's capability. For example, the Postal Service's route delivery vehicle requirement can be met within the 35 miles per hour, 30 mile range and 300 starts and stops capability of the electric vehicle we presently are producing.

Results of the demonstration phase might be more conclusive if delayed pending further development and improvement of electric power systems, and there are many who will support that position. It is our conviction, however. that the economic and ecological pressures are such that we must test the feasibility of electric vehicles in various roles in the marketplace concurrently with an all-out effort to develop lower cost, higher efficiency electric power systems.

We, therefore, firmly support legislation to promote simultaneous research, development and demonstration of electric vehicles.

Sincerely,

CRUSE W. MOSS.

Enclosure.

Question No. 1. What changes or additions would you make to S. 1632 or H.R. 8800?

H.R. 8800 would establish the following time table for implementation of the electric vehicle demonstration program:

(*a*) *Purchase number 1.*—Within one year of enactment contracts would be entered into for the purchase of "a reasonable number of electric vehicles for evaluation tests and initial in-use demonstration."

(*b*) *Initial performance standards.*—Within one year of enactment, ERDA would develop initial performance standards and criteria for purchase number 2.

(*c*) *Purchase number 2.*—Within 15 months of enactment contracts would be entered into for the purchase of at least 2,500 electric vehicles meeting the criteria developed in (b).

(*d*) Operation and evaluation of vehicles obtained under purchase number 2.

(*e*) *Revised performance standards/purchase number 3.*—Within 42 months after enactment ERDA would develop revised standards and criteria, and purchase at least 5,000 electric or hybrid vehicles exhibiting advanced performance characteristics.

(*f*) Operation and evaluation of vehicles obtained under purchase number 3.

Answer. We believe that S. 1632 in its present form provides the necessary elements of a productive program. The time allowed for the individual phases appears to be ambitious, but we think it needs to be. The schedule set forth must be adhered to and pressure must be kept on the administrators to insure that the program adheres as nearly as possible to the established schedule.

Question No. 2. What specific benefits do you see arising from such a demonstration program?

Answer. The principal benefits we see arising from such a demonstration program are:

(*a*) More rapid advance in "the state-of-the-art" resulting from concentrated research and development activity.

(*b*) An early evaluation of the capability of electric vehicles to meet the requirements of real world users.

(*c*) The feed back of this information into the research and development program.

(*d*) The introduction of electric vehicles with their lower performance characteristics into urban traffic patterns and the resultant analysis of the problems arising therefrom.

Question No. 3. Some electric vehicle proponents raise the concern that "premature" demonstration might lead to a negative public perception of electric vehicle potential due to alleged limited cost and performance characteristics of existing electric vehicles. Do you agree or disagree that this danger exists? If you agree, how might the demonstration program be restructured to avoid this problem? If you disagree, please indicate why.

Answer. There may well be some negative public perception of electric vehicle potential resulting from a demonstration program conducted with current state-of-the-art vehicles. There is no information available to us that indicates that electric vehicles are at any time likely to equal the internal combustion engine vehicles in performance. It becomes necessary, therefore, to begin educating the public to accept a lower performance vehicle. This will require a substantial public relations effort in connection with the demonstration program.

Although there are those who will contend that the demonstration program should be delayed, we believe that the rather limited increase in vehicle top speed and range that can be anticipated in the next several years will have relatively little bearing on public acceptance. Once again, it seems to us that we are going to have to learn to accept lower levels of performance if we are to enjoy the advantages offered by electric vehicles.

Question No. 4. Is one year a sufficient time in which to purchase and evaluate a baseline electric vehicle fleet of 200 to 300 vehicles, and develop performance criteria for purchase number 2? If not, what time frames would you suggest?

Answer. One year is a minimal amount of time in which to purchase and evaluate a baseline electric vehicle fleet and develop performance criteria for later purchases. Rather than suggest extended time frames, we would urge that

special attention be given to maintaining the established time frames even if in the final analysis they are forced to slip a bit.

Question No. 5. Are the time schedules for purchases number 2 and 3 appropriate? Please explain.

Answer. Similar to the initial purchase, the time allowed for purchases of number 2 and number 3 is extremely tight considering all that must be accomplished, but we would not suggest any extension.

Question No. 6. What, in your opinion, will be the state-of-the-art in electric and hybrid vehicles within 42 months of enactment of H.R. 8800, assuming enactment during 1975? What government policies would contribute most to commercialization of electric and hybrid vehicles?

Answer. From the information available to us, we have reached the conclusion that well designed electric vehicles should be capable of reaching maximum service speeds of 50 to 60 miles an hour with related improvements in acceleration, and a range of approximately 200 miles within the next three or four years.

We believe that a substantial degree of government assistance will be needed to support the commercialization of electric and hybrid vehicles. This can be accomplished in a number of ways:

(*a*) By making the maximum possible use of electric and hybrid vehicles in government fleets.

(*b*) By providing preferential subsidies for purchase of electric and hybrid vehicles by state and local governments.

(*c*) By providing preferential subsidies, attractive leasing plans, low interest loans or preferential tax treatment for privately owned electric and hybrid vehicles.

Question No. 7. In addition to battery research, where should a federal R&D program on electric and hybrid vehicles focus its efforts? How much funding should be provided for battery research and these other efforts during the next 5 years?

Answer. In addition to battery research and the demonstration program, it will be necessary to design new vehicles to accept the new propulsion systems which will provide optimum performance and safety. We are not in the battery business so do not feel qualified to estimate funding required for battery research. We urge, however, that funds be provided to support an all-out effort.

The present volume of the electric vehicle commercial market, and even the quantities contemplated in the demonstration program, are not sufficient to generate substantial private investment. It, therefore, appears to us that S. 1632, or some other program, should provide government funds for vehicle design and development. We estimate that the design and development of any individual electric vehicle would require an investment in the neighborhood of $5 million.

Question No. 8. Are there other vehicle technologies that offer comparable reduction in petroleum consumption and reduction of environmental impact to that of electric and hybrid vehicles? If so, is the special emphasis given to electric and hybrid vehicles in S. 1632 and H.R. 8800 justified? Please explain.

Answer. Although a great deal of research has been conducted in other vehicle propulsion systems, such as turbines, steam engines and the like, the electric and hybrid vehicles appear to offer the most viable alternate power source. We believe the special emphasis given to electric and hybrid vehicles in S. 1632 and H.R. 8800 is fully justified.

Question No. 9. How can an adequate manufacturing base and adequate competition be assured in electric vehicle production? Do S. 1632 and H.R. 8800 adequately address these needs? What changes or new provisions might be useful in this regard, if any?

Answer. If the program contemplated in S. 1632 and H.R. 8800 establishes the fact that there is a volume market for electric vehicles, we believe we can rely on the response of our free economy to a demonstrated need to provide an adequate manufacturing base and adequate competition. This probably would not occur for many years without the catalytic effect of S. 1632 and H.R. 8800.

While it is clear that government support and leadership is necessary at the outset because of the urgency generated by the economic and environmental pressures, it is reasonable to expect that the products needed to fill an established requirement will be provided by the private sector.

The possibility can be foreseen that at some point preferential government capital loans might be helpful in establishing a private sector production base.

Question No. 10. What infrastructure (for example, public or private recharging stations, maintenance and service facilities, etc.) must be developed to sup-

port the demonstration program called for in S. 1632 and H.R. 8800? What problems might be anticipated in establishing such an infrastructure?

Answer. The recharging stations, maintenance and service facilities required to support the demonstration program will have to simulate the complete vehicle support provided for units sold commercially. The location of these facilities will be dependent on how the demonstration vehicles are deployed. This problem may be somewhat alleviated if the initial vehicles are used by fleet operators (which seems likely) who traditionally provide their own service and maintenance facilities.

It will be important to the ultimate success of the program that the operators do have access to completely adequate facilities. The most important problems in establishing an infrastructure will be training people to service the vehicles and to provide incentive for the establishment of adequate servicing organizations.

These are problems common to the automotive industry, the solution to which relates directly to profitability.

Question No. 11. What are the performance characteristics of current technology electric vehicles? What improvements in lead-acid battery technology do you foresee in the next 5 and 10 year periods? What are the implications of these improvements for the performance characteristics and purchase and life-cycle costs of electric vehicles?

Answer. The principal peculiar performance characteristics of electric vehicles may be defined as maximum speed, acceleration, operating range and the number of starts and stops to be included within the range. Each of these characteristics is variable and because the vehicle has a definitive and exhaustible energy supply, variation in the numerical value of any one characteristic causes a compensatory variation in one or more of the other characteristics.

Current technology electric vehicles have speeds ranging as high as 40 to 50 miles per hour and maximum ranges up to 50 to 60 miles. There may be claims of higher performance values in individual instances, but they must be equated in the light of the variable relationship of one to the other.

We believe that a 50 to 100 percent increase in available energy from a given battery weight can be anticipated within the next 5 to 10 years. It is our opinion that with adequate funding and top quality talent the battery picture can be improved substantially in a relatively short period of time.

Battery improvements, either in increased storage capacity, reduction in weight or reduction in cost, all will have a favorable effect on the purchase and life-cycle costs of electric vehicles. It follows that improved performance at lower cost will make electric vehicles more competitive with internal combustion engine vehicles. When it becomes apparent that electric vehicles can compete on more even terms, we can expect the economic forces in the private sector to begin impacting electric vehicle market growth.

Question No. 12. In your opinion, what other batteries show promise of future use in electric vehicles, and on what time tables? What performance characteristics and costs will be associated with the use of these other batteries?

Answer. There are nickel-iron and nickel-zinc batteries presently under development which are expected to be available within the next two to three years. The nickel-zinc appears to be the most promising. It is expected to provide approximately three times the available energy of the present lead acid battery on the basis of weight. It is projected that per unit of energy cost will be somewhat lower than at present.

There are some more exotic new batteries under development such as the zinc-chlorine, lithium-sulfur and sodium-sulfur that appear to offer significant improvements in energy and power density. There is, however, much development work yet needed.

Funding provided through S. 1632 would significantly accelerate these battery developments, in our opinion.

Question No. 13. What problems or constraints might arise in large scale manufacture of electric cars with respect to production equipment and manpower skills? What problems might be anticipated by electric vehicle manufacturers in the areas of materials or capital availability?

Answer. We do not foresee any unusual problems or constraints associated with large scale manufacture of electric vehicles. Problems with respect to materials, manpower skills or capital would not be substantially different than for any other industry.

Question No. 14. Please state your views on the current and future applicability of safety standards and regulations to electric and hybrid vehicles.

Answer. We believe that future electric and hybrid vehicles should conform to those safety standards and regulations appropriate to that type of vehicle. There are certain speed, tire, equipment and other standards and regulations established for internal combustion engine vehicles which must be reviewed and altered as necessary so that electric vehicles will not be unreasonably ruled noncompliant.

Question No. 15. What steps might the federal government take to facilitate introduction of demonstration electric and hybrid vehicles into state and local government fleets?

Answer. The federal government can facilitate introduction of demonstration electric and hybrid vehicles into state and local government fleets in a number of ways:

(*a*) Through subsidies or financing arrangements.

(*b*) Through clear-cut persuasive presentation of the economic and environmental advantages of electric vehicles;

(*c*) By the example of including electric and hybrid vehicles in federal government fleets.

Question No. 16. What institutional impediments do you see to the widespread introduction of electric vehicles?

Answer. We think that the most serious impediment to the widespread introduction of electric vehicles will be the lack of performance by comparison with internal combustion engine vehicles and the initial high cost of the electric vehicle.

It is difficult to foresee the electric and hybrid vehicle ever fully equaling the I.C.E. vehicle in performance. To the extent that it does not, it will have a somewhat limited market. Depending on the niche that it finds in the market, it may well have the effect of changing life styles. For example, one car families who become owners of electric vehicles may well be forced into greater use of public transportation. Families with two or more cars who own an electric vehicle may find the overall use of their fleet less flexible.

Provisions will have to be made for acceptance of electric vehicles in traffic patterns because of their lower acceleration and lower top speed.

We believe that capable government leadership, expressed initially through S. 1632 and H.R. 8800, can and will solve the change over in modes of transportation required by our changing economy and protection of the environment.

EAGLE-PICHER INDUSTRIES, INC.,
Joplin, Mo., October 29, 1975.

Hon. FRANK E. MOSS,
Chairman, Subcommittee for Consumers, Committee on Commerce, U.S. Senate, Washington, D.C.

Subject: S-1632, Electric Vehicle Research, Development and Demonstration Act of 1975

DEAR SENATOR MOSS: These comments are based on our knowledge and experience in the advanced battery technology field. Eagle-Picher manufactures many different battery types, several of which are being directed to electric vehicle propulsion.

For example, we are presently conducting development or investigative programs in such systems as advanced lead acid, nickel-iron, nickel-zinc, nickel-hydrogen, zinc-air, iron-air, lithium-sulfur, and sodium-sulfur batteries. In addition, Eagle-Picher has over 25 years of experience in many other electrochemical vehicle applications by virtue of : (1) our design and development of seven ex-activated and thermal battery types. Eagle-Picher is also experienced in electric vehicle applications by virtue of: (1) our design and development of seven experimental or test vehicles, and (2) the manufacture of several hundred multi-purpose personal electric vehicles.

Eagle-Picher heartily supports this Electric Vehicle Demonstration Act but we wish to submit the following comments for your consideration:

1. The present state of development of batteries limits the performance of electric vehicles as lead-acid batteries are the only type presently available;

2. Driving range will be limited because of the unavailability of advanced batteries in a production configuration;

3. Production of a large quantity of electric vehicles with limited driving range would cause adverse public reaction;

4. The large number of vehicles specified in the first 18 months will leave insufficient funding available for near-term applied research and development for batteries, an area clearly identified as essential for electric vehicle success;

5. With specific reference to H.R. 8800, there is sufficient time to incorporate the performance standards, Section 7(b)(1), and the safety standards and regulations, Section 9(d), in the 2,500 electric vehicles, Section 7(a)(2) to be under contracts within fifteen months.

Therefore, we recommend that the number of electric vehicles in the first two years be reduced to a maximum of 500. This number of vehicles would establish the current EV state of the art, accumulate statistical data, support small electric vehicle manufacturers, and by analysis of public reaction to these vehicles, determine areas to be improved in the subsequent development of vehicles for the latter phases of the program.

We further recommend that increased emphasis be placed on development of advanced batteries using technology available in the near term. Examples of such systems are advanced lead-acid, nickel-iron, and nickel-zinc. Current lead-acid batteries have a realistic life limit of approximately one year with continual use and provide a maximum vehicle range of 20–50 miles. Using known technology advances and applying them directly to the electric vehicle application would extend life to three years and range to approximately 75 miles. These developments could be accomplished in two to three years. It is also possible in 2–3 years to advance nickel-iron and nickel-zinc batteries to provide even longer life and vehicle ranges of 100–200 miles. The following table summarizes these advanced battery capabilities:

	Currently available			Advanced		
	Wh/lb	Life (years)	Vehicle range (miles)	Wh/lb	Life (years)	Vehicle range (miles)
Lead-acid	11	1	40	17	3	63
Nickel-iron	(1)	(1)	(1)	32	5	119
Nickel-zinc	(1)	(1)	(1)	36	3	133

1 Not commercially available.

Note: These data were derived for a 3,000 lb car using a standard driving profile.

It is important to note that the development timing schedule for these advanced batteries would coincide with the procurement schedule for the 5,000 electric vehicles. Also, this additional time would allow development of new concepts for electric vehicles. Added emphasis could be given to minimizing weight and rolling and air resistance, improving electrical efficiency and maximizing safety.

We would like to stress that every user application requires a unique battery design and electric vehicles are no different. In our advanced, special purpose battery design and development experience, we have witnessed tremendous advances in battery technology when specific problems or problem areas have been identified and adequate resources have been made available for problem solving. The space program is one example of what can be accomplished given a goal and adequate interest or sponsorship. Eagle-Picher firmly believes that the necessary battery, controller, drive, and charge systems for electric vehicles can be developed in 3 to 5 years if people become committed to that goal.

Should you desire specific technical information, we will gladly meet with members of your staff at their convenience. Please have them contact either Earl Carr or the undersigned for specific arrangements or additional information.

Very truly yours,

E. M. Morse, *Manager*,
Planning and New Product Development.

CALSPAN CORPORATION,
Buffalo, N.Y., November 5, 1975.

Mr. ALLAN R. HOFFMAN,
Staff Scientist, U.S. Senate, Committee on Commerce, Dirksen Senate Office Building, Washington, D.C.

DEAR MR. HOFFMAN: Calspan Corporation (formerly Cornell Aeronautical Laboratory) has been engaged in automotive research and development since 1947. During this period our work has focused mainly on vehicle control and crash safety. The research programs have dealt, for the most part, with conventional automobile technology (internal combustion power vehicles). We have, however, performed some limited research with electric vehicles both from the standpoint of the vehicle mission performance and crash impact characteristics.

Most recently, under contract with the U.S. Department of Transportation, National Highway Traffic Safety Administration, we are engaged in Phase II of the Research Safety Vehicle (RSV) project. Under Phase I of the RSV project (completed in April 1975), we examined factors expected to influence U.S. automobile transportation between now and the end of the century. It is mainly as a result of this background that we offer comments relative to S. 1632 and H.R. 8800.

We have reviewed the questions recently submitted to us. Many of these cover areas not directly involved with our previous experience. We do provide our comments relative to certain specific areas.

Objective of the legislation

We note that the intent of H.R. 8800 is "to authorize in the Energy Research and Development Administration a Federal program of research, development, and demonstration designed to promote electric technologies and to demonstrate the commercial feasibility of electric vehicles."

Certainly the promotion of electric vehicle technology is necessary in our economy. Our studies clearly indicated that alternatives to petroleum powered vehicles must be developed in the next 20 years. The intent here should be to insure that such an alternative is intensively investigated within the next several years. Thus, we strongly support this aspect of the legislation.

On the other hand, the legislation suggests that electric vehicles are at present "commercially feasible." We doubt that such is the case in the context of our present economy. Indeed, if there exists areas where electric vehicles are competitive with conventional automotive technology, these applications are extremely small in relation to the total current use of motor vehicles. It will indeed be unfortunate if the potential success of electric vehicles is judged, for the most part, on their ability to compete under present economic conditions. We therefore recommend that if implementation of the bill results in sale to the general public of electric vehicles that are essentially state-of-the-art, every effort be made to emphasize the electric vehicle as an alternative to todays automobiles—for certain missions—rather than a competitor with them.

Potential benefit of demonstration project

With regard to potential benefits from the planned demonstration project, there may be two possible benefits, (1) encouraging the growth of a private sector electric vehicle industry, and (2) development of better data on electric vehicle performance characteristics. Certainly some stimulation of the electric vehicle industry appears to be necessary if this technology is to be advanced to a position where it provides a long range alternative to petroleum based motor vehicles. The demonstration project, if carefully controlled, could result in meaningful data on electric performance characteristics under real world operating conditions. At present, data appears to be confined to special applications which in general do not reflect typical automotive emissions.

Possible adverse affects of demonstration project

There may, however, be some severe negative aspects as noted below. We agree that a "premature" demonstration might lead to a negative public perception of electric vehicle potential. In fact, it is our feeling that this would likely be the result of such a demonstration project which involves the public at large. It must be recognized that the American public has come to expect a high degree of performance (perhaps excessively high) and reliability from their motor vehicles. Furthermore, an extensive service industry has been developed which responds to correcting problems consumers have with their automobiles.

hours per mile. Using the figure of 9,240 miles per year as above, this would require 4,620 kilowatthours per year.

According to EEI, it takes 0.076 gallons of oil to produce one kilowatthour. However, only 16.5% of the generation is from oil. Therefore, electric industry would use nationally only 0.01254 gallons of oil times 4,620 kilowatthours or fifty-eight (57.93) gallons of oil to drive one car for a year.

We do not know how much utility oil is imported, but let us suppose it fits the national pattern of 25% in 1970. That means, we would need 14.5 gallons of imported crude per car, or 14,500,000 for a milion cars. Therefore, we reduced petroleum imports by 1,577 minus 14.5 or 1,562.5 million gallons.

Question No. 2. What are the implications for the utility industry with regard to generating capacity, investment capital, and pollution control, of widespread use of elecric vehicles? Please identify any assumptions used to answer this question. What other implications does widespread electric car use have for utilities?

Answer. If one car uses 4,620 kilowatthours per year, one million cars would use 4,620 million kilowatthours per year. The total electric utility industry output for 1974 was about 1,866,000 million kilowatt-hours. Therefore, in 1974, one million electric cars would have required about one quarter of one percent of the total industry output.

In the Electrical World article referred to in the Answer to Question 1 above, the author postulates eighteen million electric vehicles in the year 2000 and estimates they would require 0.9% of total U.S. electricity production at that time.

It is anticipated that the very small increase in capacity required coupled with the high probability of electric car recharging in off-peak hours would not tend to require any substantial, country-wide increase in generating capacity. Due to the higher probability of urban usage of electric automobiles, some local requirements for urban based utilities might be required, but should not substantially change increased capacity planned due to normal growth patterns. Thus, this lack of the requirement for increased capacity would, of course, dictate that no substantial investment capital nor major increase in pollution control costs would be required. One favorable aspect of the widespread usage of electric cars with off-peak recharging will be to enable the installed capacity to operate at a higher capacity factor (no matter how small), thereby reducing the cost per kilowatthour to the customer (see Question 3).

Question No. 3. What is the estimate of the projected increase in the national average electric utility capacity factor per one million electric cars in operation? How should this increase in capacity factor translate into a reduced average power cost to the nation?

Answer. We are unable to estimate the projected increase in the national average electric utility capacity factor per one million electric cars in operation as requested.

Because so much hinges on the general public's attitude toward the electric car, we cannot predict the operational patterns, the necessary battery storage capacities, or recharging cycle requirements. If the electric car is to be used for short-range operation with limited battery capacity, then there is a good possibility that the batteries would be recharged during off-peak hours at their home base. On the other hand, we can visualize the service station of the future as providing fully charged batteries in exchange for discharged batteries. If this is the case, we would assume that the batteries would be recharged as soon as they were received by the service station in order to reduce inventory requirements and hence would be charged during both on-peak and off-peak hours. In either case, through the use of properly designed utility rates and load management, we can foresee a large portion of the battery charging being done [illegible]
resulting increase in generating efficiency and some [illegible]

Question No. 4. Water requirements for central statio[illegible]
eral times greater than they are for gasoline produ[illegible]
energy. Thus, substitution of electric cars for int[illegible]
volve substantially greater water use. How serio[illegible]

Answer. The major usage of water is in evapor[illegible]
for the petroleum and utility industries. As th[illegible]
increases as a result of electric car usage, the [illegible]
tions will increase, thereby decreasing the wa[illegible]
sumed. This, coupled with the decrease in water [illegible]
lowered gasoline production (see Question 1), [illegible]

Electric Car. Should you require any further information, please contact Dan Jaffe or Allen Hoffman of the Commerce Committee staff at (202) 224-9351.

Sincerely yours,

FRANK E. MOSS,
Chairman, Subcommittee for Consumers.

Enclosures.

QUESTIONS CONCERNING S. 1632 AND H.R. 8800

Question No. 1. Electric vehicle use will, to some extent, reduce oil imports since many central station power plants use non-petroleum fuels (coal and nuclear). Estimate the reduction in petroleum imports per 1 million electric vehicles replacing internal combustion engine cars, based on a national mix of fuels used to fire central station power plants.

Question No. 2. What are the implications for the utility industry with regard to generating capacity, investment capital, and pollution control, of widespread use of electric vehicles? Please identify any assumptions used to answer this question. What other implications does widespread electric car use have for utilities?

Question No. 3. What is the estimate of the projected increase in the national average electric utility capacity factor per 1 million electric cars in operation? How should this increase in capacity factor translate into a reduced average power cost to the nation?

Question No. 4. Water requirements for central station power plants are several times greater than they are for gasoline production per unit of output energy. Thus, substitution of electric cars for internal combustion cars will involve substantially greater water use. How serious is this problem likely to be?

[The above letter and questions was sent to the following:]

VIRGINIA ELECTRIC AND POWER CO.,
Richmond, Va., October 2, 1975.

Hon. FRANK E. MOSS,
Commerce Committee, Attention: Electric Car,
U.S. Senate,
Washington, D.C.

DEAR SENATOR MOSS: With reference to your letter of September 19, 1975 concerning the development and demonstration of electric vehicles, we are happy to answer questions related to S. 1632 and H.R. 8800.

Question No. 1. Electric vehicle use will, to some extent, reduce oil imports since many central station power plants use non-petroleum fuels (coal and nuclear). Estimate the reduction in petroleum imports per one million electric vehicles replacing internal combustion engine cars, based on a national mix of fuels used to fire central station power plants.

Answer. This involves two sets of facts: A. The petroleum used by one million internal combustion engine cars and, B. The national mix of electric utility fuels.

Taking the latter first, this is established annually by the Federal Power Commission and is also stated in the Edison Electric Institute Statistical Yearbook. An FPC news release of November 26, 1974, cited the following: Coal 43%, Gas 19.5%, Oil 16.5%, Hydro 14% and Nuclear 7%.

According to the U.S. Federal Highway Administration, Highway Statistics, the average passenger automobile went 9,240 miles in 1974. The average miles per gallon was approximately thirteen, meaning that the average car used 710 gallons. One million cars would then have used about 710 million gallons of gasoline. Of course, it takes more than 710 million gallons of crude oil to produce 710 million gallons of gasoline. A gallon of crude yields about 45% gasoline. Therefore, it would take 1,577 million gallons of crude oil for one million cars.

The question asks for the reduction in petroleum imports. It would be necessary to ascertain a current figure for percentage of our petroleum consumption which is imported (and possibly also a future percentage). The figure for 1970 from the 1974 Statistical Abstract was 25% imported. Therefore, it can be said that at least 25% of 1,577 million gallons of petroleum (i.e. crude) is eliminated if one million internal combustion engine vehicles were replaced by electric vehicles or we would reduce our imports by 394 million gallons.

In a paper presented by Argonne National Laboratory at the Third International Electric Vehicle Symposium in 1974, and quoted in Electrical World (March 15, 1974, page 156), electric automobile use is estimated at 0.5 kilowatt-

hours per mile. Using the figure of 9,240 miles per year as above, this would require 4,620 kilowatthours per year.

According to EEI, it takes 0.076 gallons of oil to produce one kilowatthour. However, only 16.5% of the generation is from oil. Therefore, electric industry would use nationally only 0.01254 gallons of oil times 4,620 kilowatthours or fifty-eight (57.93) gallons of oil to drive one car for a year.

We do not know how much utility oil is imported, but let us suppose it fits the national pattern of 25% in 1970. That means, we would need 14.5 gallons of imported crude per car, or 14,500,000 for a milion cars. Therefore, we reduced petroleum imports by 1,577 minus 14.5 or 1,562.5 million gallons.

Question No. 2. What are the implications for the utility industry with regard to generating capacity, investment capital, and pollution control, of widespread use of elecric vehicles? Please identify any assumptions used to answer this question. What other implications does widespread electric car use have for utilities?

Answer. If one car uses 4,620 kilowatthours per year, one million cars would use 4,620 million kilowatthours per year. The total electric utility industry output for 1974 was about 1,866,000 million kilowatt-hours. Therefore, in 1974, one million electric cars would have required about one quarter of one percent of the total industry output.

In the Electrical World article referred to in the Answer to Question 1 above, the author postulates eighteen million electric vehicles in the year 2000 and estimates they would require 0.9% of total U.S. electricity production at that time.

It is anticipated that the very small increase in capacity required coupled with the high probability of electric car recharging in off-peak hours would not tend to require any substantial, country-wide increase in generating capacity. Due to the higher probability of urban usage of electric automobiles, some local requirements for urban based utilities might be required, but should not substantially change increased capacity planned due to normal growth patterns. Thus, this lack of the requirement for increased capacity would, of course, dictate that no substantial investment capital nor major increase in pollution control costs would be required. One favorable aspect of the widespread usage of electric cars with off-peak recharging will be to enable the installed capacity to operate at a higher capacity factor (no matter how small), thereby reducing the cost per kilowatthour to the customer (see Question 3).

Question No. 3. What is the estimate of the projected increase in the national average electric utility capacity factor per one million electric cars in operation? How should this increase in capacity factor translate into a reduced average power cost to the nation?

Answer. We are unable to estimate the projected increase in the national average electric utility capacity factor per one million electric cars in operation as requested.

Because so much hinges on the general public's attitude toward the electric car, we cannot predict the operational patterns, the necessary battery storage capacities, or recharging cycle requirements. If the electric car is to be used for short-range operation with limited battery capacity, then there is a good possibility that the batteries would be recharged during off-peak hours at their home base. On the other hand, we can visualize the service station of the future as providing fully charged batteries in exchange for discharged batteries. If this is the case, we would assume that the batteries would be recharged as soon as they were received by the service station in order to reduce inventory requirements and hence would be charged during both on-peak and off-peak hours. In either case, through the use of properly designed utility rates and load management, we can foresee a large portion of the battery charging being done off peak with a resulting increase in generating efficiency and some improvement in load factor.

Question No. 4. Water requirements for central station power plants are several times greater than they are for gasoline production per unit of output energy. Thus, substitution of electric cars for internal combustion cars will involve substantially greater water use. How serious is this problem likely to be?

Answer. The major usage of water is in evaporation for cooling purposes both for the petroleum and utility industries. As the capacity factor (utilization) increases as a result of electric car usage, the thermal efficiency of power stations will increase, thereby decreasing the water usage per unit of energy consumed. This, coupled with the decrease in water consumption for substantially lowered gasoline production (see Question 1), should result in a net decrease

in water usage per unit of energy consumed rather than a substantial increase as implied in your question.

We hope these answers will be helpful to you in your hearings scheduled for October 7 and October 10.

Sincerely yours,

T. JUSTIN MOORE, JR.

ELECTRIC POWER RESEARCH INSTITUTE,
September 29, 1975.

Hon. FRANK E. MOSS,
Chairman, Subcommittee for Consumers (Attention: Electric Car), Committee on Commerce, U.S. Senate, Washington, D.C.

DEAR SENATOR MOSS: Dr. Chauncey Starr has asked me to respond to your letter of September 19, 1975 in which you invited comments regarding implications for the utility industry of legislation proposed under S. 1632 and H.R. 8800. Specifically, you asked for answers to Questions No. 1–4 attached to your letter.

EPRI's efforts to assess the impacts of electric vehicles on the utility industry are in a relatively early stage, and we do not as yet have a consistent set of detailed conclusions. However, on a preliminary basis we would like to respond to your questions as follows:

No. 1. Considering their technical prospects, electrical vehicles will be used primarily for urban and suburban transportation. Vehicles operating in this mode typically are driven about 20 miles per day during 250–300 days per year. Assuming that future conventional ICE vehicles would deliver 20 mpg in urban/suburban driving, a 1-million population of such vehicles would require 250–300 million gallons of gasoline, or about 7–8.5 million barrels of petroleum per year.[1] Under the likely assumption that no new oil-fired base load power plants will be constructed after 1980, most or all electric power needed for vehicle propulsion will be derived from coal and nuclear fuel bases. Thus, the petroleum savings per million electric vehicles are likely to be in the order of 8 million barrels per year.

No. 2. Electric vehicles can have appreciably better energy economy than conventional cars. A recent analysis[2] indicates that in a metropolitan driving cycle a lead-acid battery powered car could deliver 2–3 miles for each kilowatt-hour supplied by the battery. Allowing for battery inefficiency, a 1-million population of urban/suburban electric cars would require approximately 3000 to 5000 million kWh per year. For the 1985–1990 time frame, this requirement amounts to about 0.1 percent of the electric energy produced. Even if all of the charging energy had to be supplied during the daily peak demand period, the required additional generating capacity per million vehicles would be only 0.2–0.3 percent of the projected generating capacity. In this (the most unfavorable) case, the investment in new generating plants would be in the order of $1 billion. However, it is reasonable to expect that most or all of the battery charging would take place during off-peak periods (at night). This would obviate the need for new generating plants. Two qualifying remarks should be made to this point: First, shifting the battery charging load entirely to the nighttime demand valley will require somewhat more capable batteries and, probably more important, suitable timing and control equipment for charging. Second, the impact of electric vehicles will not be uniform across the country but concentrated heavily on urban utilities which, therefore, will experience considerably greater—positive or negative—impacts than the national average would suggest.

No. 3. Assuming that (1) future electric vehicles are used primarily for metropolitan driving where nighttime charging will suffice, and (2) charging can be restricted to the demand valley, then the electricity demand for electric vehicles can be satisfied entirely by increasing the load factor of baseload plants. Based on the energy requirement estimates given under No. 2, above, and assuming battery charging during a 8-hour night period (e.g. 10 p.m.–6 a.m.), the average national power requirement would translate into a 0.1–0.2 percent improvement of the annual load factor, for each million of electric vehicles served. It should be noted that the power requirements and—positive or negative—economic im-

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[1] Assuming an 85% efficiency in refining oil to gasoline.
[2] "Should We Have a New Engine," Report No. SP 43–17, Jet Propulsion Laboratory. Pasadena, California, August 1975; See Vol. II, Fig. 8–6.

pacts are likely to be substantially greater for the utilities serving the major U.S. metropolitan areas. A case-by-case analysis would be required to arrive at a meaningful estimate of how electric power costs would be affected in the national average.

No. 4. The increased cooling water requirement is directly proportional to the increased electrical energy requirement, assuming no change in power plant cooling technology. At most then, 0.1 percent more cooling water would be required by 1985 to support 1 million electric vehicles. However, several plants with water conserving cooling systems (dry and wet/dry cooling) are now being committed and will be operational by 1985. Dry and wet/dry cooling will be used on many plants in the future. In addition, high efficiency advanced generation systems introduced after 1985, such as coal gasifiers coupled to advanced combined cycles or fuel cells, and liquid metal fast breeder reactors, will reduce cooling requirements for a unit of electrical output.

Very truly yours,

FRITZ R. KALHAMMER,
Manager, Electrochemical Energy, Conversion and Storage.

OCTOBER 7, 1975.

Hon. FRANK E. MOSS,
U.S. Senate, Committee on Commerce,
Washington, D.C.

DEAR SENATOR MOSS: Thank you for your letter dated September 19, 1975, concerning Senate Bill S. 1632, "Electric Vehicle Research, Development and Demonstration Act of 1975". Below you will find my personal opinions about the present status and projections of battery technology pertinent to electric vehicle propulsion. I have appended a couple of technical papers coauthored by myself, which will help support the statements I have made. If you would like additional information to supply the rationale behind any of these opinions, I shall be pleased to send you such information under separate cover.

Lead-acid batteries are used in present-day vehicles, and will be used in vehicles built in the future, not because of their technical (performance) characteristics, but because of their relatively low cost and availability. In addition, the motoring public are already familiar with such battery systems, and this may mean a psychological advantage in terms of consumer acceptance.

The technical performance of lead-acid batteries may be acceptable for certain applications, but a weight and volume penalty must be paid, making the vehicles heavier, or larger than they need be if improved battery systems were available. For compact, lightweight vehicles other battery systems must be developed. When reliability has been established for these alternate battery systems, inexpensive fabrication methods, and materials optimization will be necessary to reduce costs to at least those of present-day suitable lead-acid battery systems.

Over the next 5 years, I would expect only to see about a 10 to 15 percent improvement in the performance of lead-acid batteries. Measured at the 1-hour rate of discharge, the energy density might reach 20 watt hr/lb in terms of weight, or 1.0 watt hr/in^3 in terms of volume. Costs will not change appreciably. At the end of a decade, a further small improvement in performance will be evident. At this time the energy density would approach 25 watt hr/lb, or 1.5 watt hr/in^3. Costs will only be reduced if large-scale manufacturing capabilities (like present day facilities for SLI automotive batteries) are realized.

Major breakthroughs in battery (hence vehicle) performance will only be achieved with the development of other battery systems. Thus, although lead-acid batteries will be the main contender in the 1975–1980 time period, nickel-zinc, zinc-chlorine and zinc-air batteries could reach a satisfactory state of development for applications in 1980–1985. Of these three battery systems, nickel-zinc batteries will be probably the best contender for superseding the lead-acid system. Beyond 1985, in order to meet the (high) performance requirements of some types of vehicle an effort has to be made to develop some of the so-called "advanced" systems, such as sodium-sulfur or lithium-metal sulfide, which operate at elevated temperatures (say 500 to 750 F), or the sodium-metal chloride system which operates at about 400 F.

Until these alternate battery systems can be incorporated into electric vehicles, the performance obtained with lead-acid batteries may be considered less than desirable by the public. To compensate for this other aspects of battery-

powered vehicles should be emphasized such as reduced noise and air pollution, reduced operating costs, and simplicity of operation and maintenance.

At the same time improvements in battery systems are being sought, consideration should be given to the development of compatible battery charging systems, whether on-board or stationary, for those situations where overnight recharging is not possible or practical.

I hope the above comments will assist you and your colleagues in preparing for the Commerce Committee hearings on S. 1632 and H.R. 8800 scheduled for October.

Very truly yours,

ERIC W. BROOMAN, Ph. D., M.I.M.

Enclosures (3).

BATTERIES: PROSPECTS FOR ELECTRIC VEHICLES

Main hang-up in electric vehicle development is batteries. Currently, design engineers must use the old reliable lead-acid type. However, progress is being made and some new high-performance batteries are ready for evaluation in vehicles.

By Eric W. Brooman and John E. Clifford, Battelle Columbus Laboratories, and Donald E. Semones, Gould Inc.

Electric vehicles were very popular at the turn of the century. Their speed of 20 miles per hour and range of about 30 miles were sufficient for a time. However, as the roads and highway system developed, long distance traveling became more practical, and higher speeds were desired. The internal combustion engine took over.

Considering the overall picture, electric vehicles for personal transportation require higher speeds and longer range, while many industrial needs can be met by low speeds and shorter ranges. For example, a speed of 5 to 10 mph, with a range of about 5 miles, is acceptable for a fork-lift truck in a plant.

With the increasing emphasis on energy conservation, safety, and environmental impact, a compromise is becoming more socially acceptable for personal transportation. Electric vehicles are being considered for industrial in-plant travel, delivery trucks, urban travel and suburban travel. This makes them more competitive, in terms of performance and cost, with the internal combustion engine automobile.

For the present 55 mph maximum speed limit, less power is required. Previously, a top speed of about 50 mph was considered inadequate for electric vehicles on highways. This speed is now adequate.

Early electric vehicles, such as the 1914 Rauch & Lang, were usually powered by lead-acid type batteries, but nickel-iron batteries were sometimes considered, even by Henry Ford. Although heavy, with a low specific power (watts/lb) and specific energy (watt-hours/lb), they were mass produced, hence available and inexpensive.

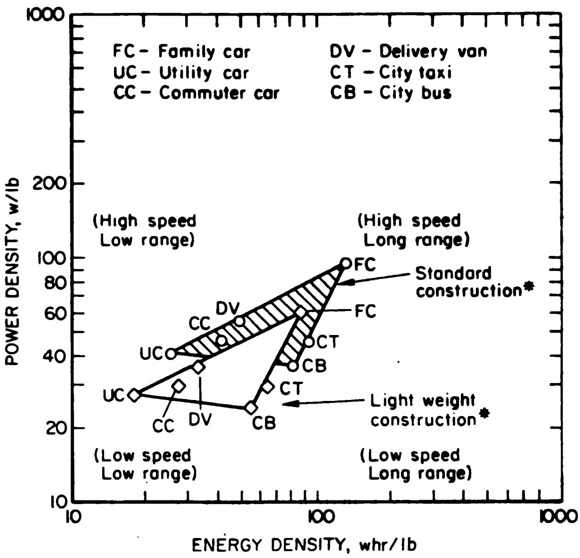
Developments over the years have improved the performance of lead-acid batteries, and these old "work-horses" have kept alive materials handling vehicles, delivery trucks, golf carts, and in-plant personnel carriers. Other survivors include the large fleet of electric vehicles continuously operated in the United Kingdom, primarily for milk delivery routes.

Other components of the vehicle are now being developed, for example tailored transmission systems, controls and regenerative brakes. However, the main drawback to widespread application is still the need for improved batteries.

No perfect battery

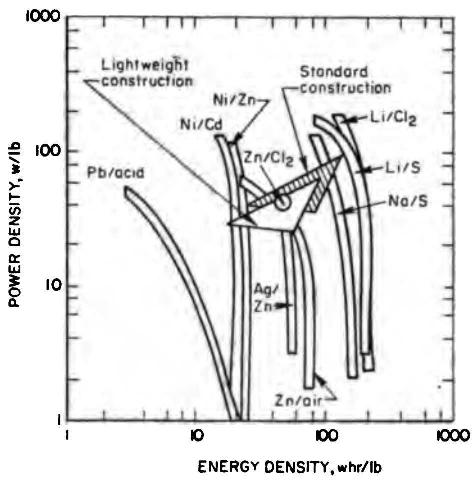
Specific power and specific energy of batteries are usually related in an inverse manner. A battery with high specific power normally has a low specific energy, and vice-versa. The charge/discharge life (number of cycles to unacceptable performance) is another performance factor that is important for selecting batteries for a particular application. Cycle life is also inversely related to another parameter, the depth of discharge, which reflects the amount of the capacity involved in a charge/discharge cycle as a function of the rated capacity of the battery. Ideally, an achieved 100 percent depth of discharge (use of the total battery capacity) would mean no weight penalty for the battery because of non-utilized active materials. In practice, however, there is a weight penalty because the rated total capacity is always less than the capacity calculated from the weight of materials incorporated into the battery. For example, additional materials are needed for packaging, electrical contacts and separator materials.

An ideal battery — one with high specific power and high specific energy, long cycle life and 100 percent utilization of active materials — cannot be made. The design engineer must reach a compromise between speed and range, and life and weight. Alternatively, the engineer must consider hybrid battery systems to optimize electric vehicle performance. Thus a battery with high specific power to give higher speeds can be used along with a battery having a high specific energy to give better range. These batteries usually will not



*REFERS TO VECHICLE, NOT BATTERY CONSTRUCTION

1. Desirable electrical performance characteristics of batteries for electric vehicles.



2. Specific energy density and specific power density for selected batteries and suggested performance envelopes for electric vehicles.

be of the same type, since some battery types can give relatively high specific power values, while others can give high specific energy values.

What values of specific power and specific energy are required for electric vehicles? The values proposed for a 1500 lb battery in a family-type car for highway travel were identified by the Health, Education and Welfare Department to include a specific power of ≥ 100 whr/lb and a cycle life of ≥ 3000 cycles. Similar anticipated performance numbers for other types of electric vehicle are summarized in Fig. 1. The U.S. Department of Commerce has suggested similar performance levels, while the Department of Transportation has estimated that an all-electric vehicle with a range of 200 miles at 60 mph would require a battery giving 135 whr/lb and 100 w/lb.

Because of the availability of lead-acid batteries for near-term applications to electric propulsive systems, these batteries will be discussed first. Other candidate batteries will be compared with the lead-acid types.

These other candidate batteries have been arbitrarily divided into three groups:

- Systems developed as batteries for nonpropulsive applications and not yet comprehensively evaluated.
- Prototype battery systems ready for evaluation in electric vehicles.
- Experimental systems being studied in laboratories prior to scale-up for propulsive applications.

Lead-acid still first

The lead-acid battery is still America's main SLI (starting-lighting-ignition) battery, primarily because of low materials and manufacturing costs. Also, the performance of the relatively low cost lead-acid traction battery is adequate for certain useful applications such as short distance, low speed, trips in lightweight electric vehicles. For these reasons, perhaps the lead-acid system should be more fully exploited toward propulsion ap-

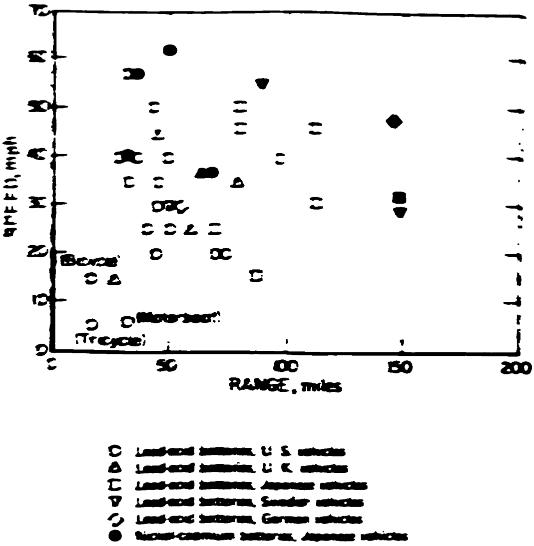
plications in the United States while alternative batteries are being developed.

The technical demands in Fig. 1 were first identified in the mid to late 1960's and a significant gap remains between performance of the lead-acid battery and performance proposed for idealized vehicle propulsion applications. Table 1 indicates that a specific power or specific energy (at a one hour rate of discharge) of only about 15 w/lb or watt-hours/lb, respectively, is commonly achieved. However recent developments in the U.S. and Japan have pushed these values to about 20-25 whr/lb. A specific power or energy value of about 25 w/lb or whr/lb, respectively, is thought to be the upper limit at the present time. The cycle life also has to be improved.

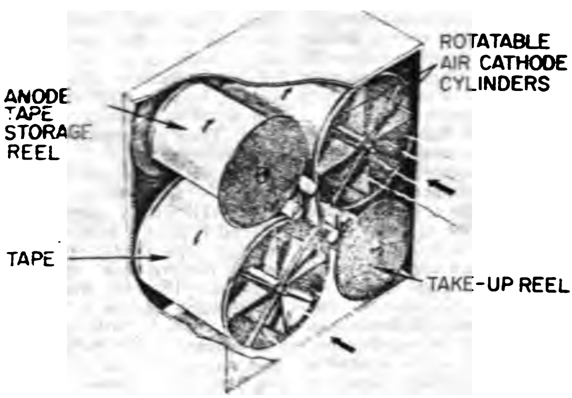
Also available . . .

Table 1 compares achieved energy densities for rechargeable batteries that have been considered for electric propulsion systems. The so-called super batteries being developed have very high theoretical capabilities, yielding calculated energy densities four to five times the achieved values of Table 1. For example, the sodium-sulfur battery has a theoretical energy density calculated at about 350 whr/lb and a maximum achieved value to date of 68 whr/lb. The usual performance leveler for these packaged batteries is in the packaging design which requires grid supports, separators, terminals, intercell connectors, case, and electrolyte all of which add to weight. The total of these additions in many instances is over 80% of the packaged battery weight. Also, it is common practice to include additional active materials, since no battery utilizes 100% of the active material at either its maximum rate or for repetitive usage.

In a sense, Table 1 only represents generalized capabilities, because the rate of discharge (power output) is not indicated, nor does the figure give a clue as to repetitive usage (cycle life of the battery) at that rate. Also not obvious in Table 1 is the afore-



3. Speed and range for electric vehicles reported by various manufacturers.



4. Air cathode is unique feature of zinc-air prototype.

mentioned general trend that the higher power of a battery was attained at a sacrifice in the energy. Alternatively, high energy was achieved at lower power outputs.

Nickel-cadmium batteries. The Ni-Cd system is a commercially successful battery with a long standing history of use for cranking trucks, marine engines and diesel locomotives, and as motive power for fork lift trucks, mine shuttle cars, locomotives, and as motive power for fork lift trucks, mine shuttle cars, and railroad switching locomotives. Although power and energy densities are reasonably good and cycle life is excellent, the world's limited supply of cadmium has discouraged its use for a large volume market comparable to lead batteries. The battery is capable of an energy density of up to 15 whr/lb, and power outputs as high as 250 w/lb, which would make it suitable for delivery trucks, and possibly for urban travel.

Silver-zinc batteries. The Ag-Zn system is also accepted commercially, but is largely used for premium applications such as for electric watches and hearing aids (primary batteries) because of the high cost of silver. The secondary battery has many uses in military applications, but because of its limited cycle life and high cost, it should be viewed only as a comparison point in Table 1. The system has outstanding power and energy density capabilities, being as high as 200 w/lb and 75 whr/lb, respectively, with a value of about 45 whr/lb being easily achievable.

Nickel-Zinc Batteries. The Ni-Zn system is receiving more attention currently because of its potential in combining the high rate discharge capability of zinc in an alkaline electrolyte with the proven nickel oxide active material at a cost lower than silver oxide. In any battery system having a zinc electrode, basic problems exist with the zinc electrode during charge-discharge cycling which results in a reshaping of the zinc electrode with ultimate deterioration (shedding). In addition, the formation of zinc dendritic growths during recharging of the battery leads to separator penetration and subsequent battery shorting. However, the Ni-Zn system has shown up to 40-50 whr/lb at low rates of discharge, and a power density as high as 160 w/lb for high rates of discharge. These values make this battery system a contender for all except highway vehicle types, if the life cycle can be improved.

Ready for road testing

Zinc-air (oxygen) batteries. Recharge problems associated with the air electrode and with the zinc electrode mentioned earlier remain as perhaps the biggest challenge with these systems, particularly for in-place charging for propulsion applications. Sketch of a typical zinc-air cell is shown in Fig. 4. The present upper limit to energy density appears to be about 100 whr/lb. Power densities as high as 103 w/lb have been measured for mechanically rechargeable batteries. For secondary batteries the upper limits appear to be about 40 w/lb.

Sodium-Sulfur Batteries. The high temperature cells, such as the sodium-sulfur type, have gained attention because of prospects of meeting both the high energy density and high power density demands of the typical high powered family car. The battery is operated at temperatures in excess of 575 F. Power density is good at these temperatures. Undesirable problems encountered with this type of battery system include materials corrosion, hazards of liquid alkali metals, battery start-up time, and initial heat source requirements. These problems still have to be overcome.

In 1967, researchers for Ford Motor Co. divulged a sodium-sulfur cell which operates at 575-660 F using a beta-alumina ceramic type electrolyte. Projected performance was 150 whr/lb and 100 w/lb. While this development appears to be continuing, there is little information released. A 12-v battery has been reported capable of delivering 300-400 w. Corresponding energy and power densities (excluding weight of heaters and insulation) were 42 whr/lb and 95 w/lb, respectively. Single cells now have a life of 6000-8000 hours.

Other groups have described developments on high temperature cells. For example, a Japanese-developed system produced 68 whr/lb at a 3-hour rate, and demonstrated 100 cycles. Perhaps the outstanding characteristic of these systems is their potential for high rate recharges (within 15-30 min) for automotive usage. In the United Kingdom a delivery van has been equipped with a Na-S battery prototype to evaluate its potential.

Lithium-Sulfur Batteries. These batteries are typical of metal-chalcogen systems which usually incorporate lithium metal as the anode material and a chalcogen such as sulfur, selenium, tellurium (or a mixture of two or more of these) as the cathode reactant. These batteries have a fused salt electrolyte, and operate at temperatures, up to about 700 F. They can deliver high energy and power densities of the order of 100 whr/lb and 50 to 70 w/lb. One source, however, estimates it would take about seven years to develop a 20 kw lithium-sulfur battery for electric automobiles.

Zinc-Chlorine Batteries. A novel zinc battery has also been reported which incorporates a rechargeable chlorine electrode by storing the chlorine externally to the cell in the form of a solid, chlorine hydrate. The hydrate allows for storage at close to ambient temperatures and pressures. The developers have demonstrated a 200 v, 100 amp modular system weighing 2010 lb. This system was installed in a Chevrolet Vega automobile having a total weight of 4614 lb, including two passengers. The energy density for a mass-produced battery was projected at 50 to 74 whr/lb at a 4-hr rate. Such a battery was expected to have an intermittent power density of 40 to 60 w/lb. The system is still under development with more recent studies concerning the porous graphite (carbon) structures used for the chlorine electrode, and operation in the flow-through mode. A single-cell

Table — [illegible]

Battery System	[illegible]	[illegible]	[illegible]		[illegible]
			[illegible]	[illegible]	
Lead-Acid	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Nickel-Cadmium	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Nickel-Iron	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Nickel-Zinc	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Silver-Zinc	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Zinc-Chlorine	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Zinc-Air	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Sodium-Sulfur	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Lithium-Sulfur	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

(a) [illegible]
(b) [illegible]

battery has given [illegible] charge-discharge cycles without degradation of the electrode, while performance showed a slight improvement. These results were interpreted to show an extremely stable electrode capable of cycling as required in a [illegible] type battery.

[illegible]

Lithium-chlorine batteries. These high temperature batteries are in the advanced experimental stage. Techniques such as absorbing the gas in porous carbon electrodes have been devised to avoid handling gaseous chlorine. Single cells have been built and life tested for over [illegible] hr and the best energy density reported for a scaled up cell is about [illegible] whr/lb.

Lithium-water batteries. A cell has recently been announced producing electricity from an alkali metal like lithium, and water with a direct, controlled combination of the reactants. The cell requires neither membranes, alloys (amalgams), nor separators. Energy efficiency is expressed in terms of the weight of lithium with achieved energy densities as high as 1000 whr/lb of lithium. For this reason, it is not given in Table 1. The results of two years of continuous operation of cells show no signs of deterioration or loss of capacity. The system is expected to be capable of up to 100 whr/lb. with maximum power density of 90 w/lb.

The cell is continuing under development for both military and commercial applications, but it is perhaps too early to comment on its potential in the marketplace as a competing power package. If considered for electric cars, purified water would have to be carried as a fuel, unless a water recycling system could be developed. Also, it would appear that a mechanical recharge is required for the lithium electrode.

[illegible]

The battery systems discussed cover a wide range of specific energy and power densities. In general, those batteries which have reached a relatively advanced state of development, and have existing manufacturing capacity fall in the low range of specific energy and power densities. As shown in Fig. 2, the [illegible] batteries are only suitable for stop-gap measures for low rate applications. For high rate applications, all the batteries capable of providing high specific power and energy densities are still under development, e.g., sodium-sulfur, lithium-sulfur, zinc-chlorine, and lithium-chlorine batteries. These batteries must reach an improved level of development to meet the proposed performance requirements for electric vehicles having a high discharge rate capability for acceptable acceleration and hill climbing performance.

Fig. 3 shows data on the speed and range of various electric vehicles as reported by the manufacturers. The vehicles span a range of applications, and therefore differ widely in weight and size, and should not be compared directly. The results illustrate that at speeds of about 40 to 50 mph, the travel distance is in the range of less than 100 miles and closer to 50 miles for vehicles propelled by lead-acid batteries.

The Chevrolet Vega was powered by a zinc-chlorine battery. The Vega data point is based on a single performance [illegible] at a [illegible]-mile course at [illegible] mph, and [illegible] the battery [illegible] [illegible]. However, performance is not reported that would simulate urban driving involving charge-discharge cycling of the battery. The three-wheeled motorcycle type vehicle was powered by silver-zinc batteries, and completed a [illegible] mile round trip at speeds of [illegible] to [illegible] mph without recharging.

[illegible]

So far, it has been inferred that the vehicles discussed have been powered by an all electric propulsion system. This imposes conflicting requirements on the source of electric propulsion. There are energy/power requirements for steady vehicle operation (low rate applications) which some batteries can meet, and there are requirements for high rate power deliveries, such as for acceleration and hill climbing. In conventional battery technology, either one or the other constraints are taken for the design parameters, and then trade-offs are made to make the battery more suitable for a particular application. However, a compromise solution is always obtained, and it is for this reason that there has been much discussion about hybrid electric vehicles — whether electric-electric, or otherwise. One energy source is designed for low rate applications, the other for high rate applications. The resulting system then is better able to meet the design specifications laid down for the various categories of electric vehicle envisaged. This type of hybrid solution to the propulsive requirements gives a much greater choice of battery systems for electric vehicles. ♠

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THE DEVELOPMENT STATUS OF BATTERIES AND FUEL CELLS FOR ELECTRIC VEHICLES

ABSTRACT

The development status of batteries and fuel cells for electric automobiles is discussed. Comparative performance data are reviewed for commercially available lead-acid batteries and potential alternatives of various types such as zinc-air, sodium-sulfur, organic electrolyte batteries, and fuel cell/battery hybrids. Available information on newly reported battery systems such as lithium-water, zinc-chlorine, and other energy storage systems is included. The comparison indicates that the zinc-chlorine, zinc-air, nickel-zinc, lithium-sulfur, sodium-sulfur, and lithium-chlorine batteries can provide the highest energy and power densities. These batteries approach performance levels for vehicle performance described in Government funded studies. Such batteries are still under development to improve practical features such as cycle life and materials stability. Meanwhile, the lead-acid battery is being used by many companies to provide valuable data for vehicle system development and to propel prototype production vehicles. However, these vehicles have a wide range of performance characteristics that differ from the vehicle performance levels described in the Government funded studies.

INTRODUCTION

This review is based primarily on data extracted from two previous symposium proceedings[1,2] that addressed the same general topic of vehicle propulsion by batteries. Data published since these symposia were held have been reviewed and integrated with these earlier data to give an up-to-date picture of the present status of batteries that are in contention for propulsive systems.

The development status of batteries and fuel cells for electric vehicles is such that more concentrated effort is needed to determine whether any candidate exists to rival the status of advanced development occupied by the lead-acid battery. Much work has been done towards identifying potential alternatives to the lead-acid battery for electric vehicle applications, because there are strong environmental and energy conservation incentives today for using batteries or fuel cells in electric cars or hybrid-electric cars.

To date, the lead-acid system is the one candidate battery that has the existing manufacturing capability to be produced in sufficient quantity for mating with vehicle propulsion systems for near term applications. Some of the better known examples of commercially successful applications of lead-acid batteries in electric vehicles include the more than 70,000 small electric trucks that deliver milk and bread in England. In Manhattan, electric vans are operated by the United Parcel Service. Also, the U.S. Postal Service is currently evaluating 30 electric trucks for mail delivery in Cupertino, California. Figure 8,* later, shows data points that illustrate present performance characteristics reported by various companies who are producing electric vehicles for these and other applications in the United States and in other countries. A satisfactory vehicle performance is being achieved in many of these applications without necessarily meeting all the vehicle performance levels of Government funded studies that are discussed in subsequent paragraphs.

One scientist[3] in the field estimated in October, 1973, that it might require 10 years or longer to develop an advanced new battery, and that it might require tens-of-millions of dollars for the development. The long term goals of such a development were suggested as first, to encourage use of urban electric cars for short distances in an integrated transit system, and second, to increase total operating distance for an all-electric vehicle. Meanwhile, fuel shortages for

[1] *Proceedings of the Symposium on Batteries for Traction and Propulsion (March 7-8, 1972), Columbus, Ohio.*

[2] *Extended Abstracts of the Battery Division of the Electrochemical Society, Fall Meeting (October 7-11, 1973), Boston, Massachusetts.*

[3] *"Electric Vehicle Battery Research and Development", H.J. Schwartz, Extended Abstracts of the Battery Division of the Electrochemical Society, Fall Meeting (October 7-11, 1973), Boston, Massachusetts, p 28.*

See pages 6-13 for exhibits.

internal combustion engines have since received much attention by the press, the public, and our legislators. These shortages may serve as an additional catalyst for the adoption of such proposed development programs when other means of propulsive power are needed.

BATTERIES AND THEIR ACHIEVED PERFORMANCE

Because of the availability of lead-acid batteries for near-term applications to electric propulsive systems, these batteries will be discussed first. In subsequent sections other candidate batteries will be reviewed and compared with the lead-acid types.

These other candidate batteries have been arbitrarily divided into three groups. The first group comprises systems which have been developed as batteries for nonpropulsive applications, and which have yet to be comprehensively evaluated for propulsive applications. The second group consists of prototype battery systems which have reached a sufficient stage of development to be evaluated in electric vehicles. The third group comprises experimental systems which are still being studied in the laboratory prior to scale-up for propulsive applications.

In general, the discussion of electric vehicle batteries is directed toward a single-type of battery system used to provide all of the motive power for the vehicle which requires a combination of power capability (speed), and energy capability (distance) in the same type of battery. Alternatives are battery-external combustion engine hybrids and battery-hybrids in which one type of battery is used to meet the high power density requirement and another type of battery is used to meet the high energy density requirements.

Lead-Acid Batteries

The lead-acid battery has been used for many applications since its origin 100 plus years ago. The lead-acid battery has come a long way since 1902, when Henry Ford was disappointed by its performance in his "Locomobile". However, the lead-acid battery still dominates[*] as America's main SLI (starting-lighting-ignition) battery today, primarily because of low materials and manufacturing costs. Also, the performance of the relatively low cost lead-acid traction battery is adequate for certain useful applications such as short distance, low speed, trips in light weight cars. For these reasons, perhaps the lead-acid system should be more fully exploited toward propulsion applications in the United States during the time while alternative batteries are being developed.

Figure 1 shows data that should be emphasized about the capabilities of the lead-acid battery.[4] In Figure 1, a performance factor known as the energy density is shown as watt hours per pound (whr/lb). This factor largely determines the possible range of the vehicle. The other factor known as power density is shown as watts per pound (w/lb), and this factor largely determines the performance of the vehicle. Both factors refer to weight in pounds of battery. The energy density and power density are interdependent, and in any application the battery should be selected to optimize the tradeoff between lowered energy density that accompanies increased power demands. The same general relationship must be recognized for other batteries that are now receiving attention for electric vehicle applications.

The charge-discharge life (cycle life to failure) is another performance factor that is important for the selection of batteries for a specified application. Figure 2 shows a dependency of the cycle life upon another battery parameter, depth of discharge, which reflects the percent of active materials involved in the cycle[5] as a function of the rated capacity of the battery.

Ideally, an achieved 100 percent depth of discharge would mean no weight penalty for the battery because of nonutilized active materials. In practice, however, there is a weight penalty because the rated capacity is always less than the capacity calculated from the weight of active materials incorporated. The cycle life attained is lowered as more active materials are consumed during discharge. For example, Figure 2 shows greater than 1000 cycles for 50 percent depth of discharge (perhaps only 25 percent utilization of active materials); while no more than about 500 cycles at 80 percent depth of discharge. For these reasons, the design engineer must reach a compromise between the weight penalty incurred because of nonutilization of active materials and the cycle life desired in the application.

The data in Figures 1 and 2 encompass results for SLI-type batteries at high power density and low energy density, as well as results for heavy duty, traction-type batteries at low power density and high energy density performance.

Figures 1 and 2 can be used to illustrate performance expectations for vehicle propulsion applications. The performance numbers for a proposed 1500 lb [680 kilograms (kg)] battery in a family-type car were identified[6] by the Health, Education and Welfare Department to include:[7]

Power $\gtrsim$ 100 w/lb (220 w/kg)
Energy $\gtrsim$ 100 whr/lb (220 whr/kg)
Life $\gtrsim$ 3000 cycles

Similar anticipated performance numbers for other types of idealized electric vehicles are summarized in Figure 3 for standard construction vehicles and what might be required for light weight construction vehicles.[8]

The U.S. Department of Commerce has suggested performances at the levels of 100 w/lb (220 w/kg), and 100 whr/lb (220 whr/kg), while the U.S. Department of Transportation has estimated[8] that minimum energy and power required for an all electric vehicle with a 200 mile [320 kilometers (km)] range at 60 mph (96 kmph) would be 135 whr/lb (297 whr/kg).

[*] *In 1972, lead-acid batteries constituted about 80 percent of a total battery market of around 2000 million dollars.*

[4] *"Zinc-Air Batteries for Traction and Propulsion", P. L'Enfant, Proceedings of the Symposium of Batteries for Traction and Propulsion (March 7-8, 1972), Columbus, Ohio, p 175.*

[5] *"Batteries for the Hybrid Heat Engine/Electric Vehicle", J.R. Kettler, Proceedings of the Symposium on Batteries for Traction and Propulsion (March 7-8, 1972), Columbus, Ohio, p 226.*

[6] *"Batteries for Ground Transportation Systems", M. Salomon, Proceedings of the Symposium on Batteries for Traction and Propulsion (March 7-8, 1972), Columbus, Ohio, p 33.*

[7] *"Prospects for Electric Vehicles", J.H. George, L.J. Stratton, and R.G. Acton, Report to Department of Health, Education, and Welfare, May 15, 1968.*

[8] *"Current Developments in Electric Ground Propulsion Systems", J.D. Busi and L.R. Turner, Extended Abstracts of the Battery Division of the Electrochemical Society, Fall Meeting (October 7-11, 1973), Boston, Massachusetts, p 31.*

and 100 w/lb (220 w/kg), respectively. These technical demands in Figure 3 were first identified in the mid to late 1960's. However, a significant gap remains between the performance of the lead-acid battery shown in Figure 1 and that performance proposed for idealized vehicle propulsion applications in Figure 3.

Developed Batteries

Figure 4 compares achieved energy densities for a number of rechargeable batteries that have been considered for electric propulsion system. The so-called super batteries being developed have very high theoretical capabilities, which yield calculated energy densities four to five times the achieved values of Figure 4. For example, the sodium-sulfur battery has a theoretical energy density calculated at about 350 whr/lb (770 whr/kg) and a maximum achieved value to date of 68 whr/lb (150 whr/kg). The dashed line represents a value that is more typically obtained. The usual performance leveler for these packaged batteries is in the packaging design which requires addition of weight of grid supports, separators, terminals, intercell connectors, case, and electrolyte. The total of these additions in many instances is over 80 parcent of the packaged battery weight. Also, it is common practice to package extra weights of active materials, since no battery utilizes 100 percent of the active material at either its maximum rate or for repetitive usage, as was illustrated for the lead-acid battery in Figures 1 and 2.

In a sense, Figure 4 only represents generalized capabilities, because the rate of discharge (power output) is not indicated, nor does the figure give a clue as to repetitive usage (cycle life of the battery) at that rate. Also not obvious in Figure 4 is the aforementioned general trend that was earlier shown in Figure 1 when the higher power of a lead-acid battery was attained at a sacrifice in the energy density. Alternatively, high energy density was achieved at lower power outputs.

Figure 5 shows the relative status of development of additional battery systems that have been mentioned as systems being in contention for electric vehicle propulsion.

Nickel-Cadmium

The Ni-Cd system is a commercially successful battery with a long standing history of usage for cranking of trucks, marine engines and diesel locomotives, and as motive power for fork lift trucks, mine shuttle cars, and railroad switching locomotives, for example.[21] Although power and energy densities are reasonably good in Figure 4, and cycle life is excellent, the world's limited supply of cadmium has discouraged its use for a large volume market comparable to lead batteries. The battery is capable of an energy density of up to 15 whr/lb (33 whr/kg), and power outputs as high as 250 w/lb (550 w/kg).

Silver-Zinc

The Ag-Zn system is also accepted commercially, but is largely used for premium applications such as for electric watches and hearing aids because of the high cost of silver. The battery also has many uses in military applications, but because of its limited cycle life and high cost, it should be viewed as a comparison point in Figure 4 only. However, the system has outstanding power and energy density capabilities, being as high as 200 w/lb (440 w/kg) and 75 whr/lb (165 whr/kg), respectively, with a value of about 45 whr/lb (99 whr/kg) being easily achievable.

Nickel-Zinc

The Ni-Zn system is receiving more attention currently because of its potential in combining the good rate capacity of zinc in an alkaline electrolyte with the proven nickel oxide active material at a cost lower than silver oxide. In any battery system having a zinc electrode, basic problems exist with the zinc electrode during charge-discharge cycling which results in a reshaping of the zinc electrode with ultimate deterioration (shedding). In addition, the formation of zinc dendritic growths during recharging of the battery leads to separator penetration and subsequent battery shorting. However, the Ni-Zn system has shown up to 40-50 whr/lb (88-110 whr/kg) at low rates of discharge, and a power density as high as 160 w/lb (350 w/kg) for high rates of discharge.

Prototype Batteries

Zinc-Air (Oxygen)

The prospects for this zinc system were covered adequately in a review[9] which included mechanically rechargeable designs as well as conventional secondary types (i.e., electrically rechargeable). The solution to the recharge problems associated with the air electrode and with the zinc electrode mentioned earlier remains as perhaps the biggest challenge with these systems; particularly for in-place charging for propulsion applications. The present upper limit to energy density appears to be about 100 whr/lb (220 whr/kg). Power densities as high as 103 w/lb (227 w/kg) have been measured for mechanically rechargeable batteries. For secondary batteries the upper limits appear to be about 40 w/lb (88 w/kg).

Sodium-Sulfur

The high temperature cells, such as the sodium-sulfur type have gained attention because of prospects of meeting both the high energy density and high power density demands of the typical high powered family car described in this paper. The battery is operated at temperatures in excess of 575 F (300 C). Power density is good at these temperatures, but undesired effects are encountered that include materials corrosion, hazards of liquid alkali metals, start-up time for the battery, and initial heat source requirements. These problems still have to be overcome.

In 1967, researchers for Ford Motors divulged a sodium-sulfur cell which operates at 575-660 F (300-350 C) using a beta-alumina ceramic type electrotyte. Projected performance was 150 whr/lb (330 whr/kg) and 100 w/lb (220 w/kg). While this development appears to be continuing, there is little information released. A 12-volt battery has been reported[10] capable of delivering 300-400 watts. Corresponding energy and power densities (excluding weight of heaters and insulation) were 42 whr/lb (92 whr/kg) and 95 w/lb (210 w/kg), respectively. Single cells now have a life of 6000-8000 hours.

[21] *"Alkaline Storage Batteries", S.U. Falk and A.J. Salkind, John Wiley & Sons, Inc., New York, New York (1969), p 472.*

[9] *"Candidate Batteries for Electric Vehicles", S. Gross, Proceedings of the Symposium on Batteries for Traction and Propulsion (March 7-8, 1972), Columbus, Ohio, p 11.*

[10] *"The Sodium-Sulfur Battery", R.P. Tischer, Extended Abstracts, 72-1, The Electrochemical Society (1972), p 434, Abstract No. 170.*

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Other groups have described developments on high temperature cells and these are reviewed elsewhere.[illegible] For example, a Japanese-developed system[illegible] produces 68 whr/lb (150 whr/kg) at a 3-hour rate and demonstrated 100 cycles. Perhaps the outstanding characteristic of these systems is the potential for high rate recharges (within 15-30 minutes) for automotive usage.

Lithium-Sulfur

These batteries are typical of metal-chalcogen systems which usually incorporate lithium metal as the anode material and a chalcogen such as sulfur, selenium, tellurium (or a mixture of two or more of these) as the cathode reactant. These batteries have a fused salt electrolyte and like the sodium-sulfur types operate at elevated temperatures, up to about [illegible] F ([illegible] C). They can deliver high energy and power densities of the order of 100 whr/lb (220 whr/kg) and 50 to 70 w/lb (110 to 154 w/kg). One source,[illegible] however, estimates that it would take about seven years to develop a 25 kilowatt lithium-sulfur battery for electric automobiles.

Zinc-Chlorine

A novel zinc battery has also been reported[illegible] which incorporates a rechargeable chlorine electrode by storing the chlorine externally to the cell in the form of a solid chlorine hydrate. The hydrate allows for storage at close to ambient temperatures and pressures. The developers have demonstrated[illegible] a 200 volt, 100 ampere modular system weighing 2010 lb (914 kg). This system was installed in a Chevrolet Vega automobile having a total weight of 4614 lb (2097 kg), including two passengers. The energy density for a mass-produced battery was projected at 50 to 74 whr/lb (110 to 165 whr/kg) at a 4-hour rate. Such a battery was expected to have an intermittent power density of 40 to 60 w/lb (88 to 132 w/kg). The system is continuing under development[illegible] with more recent studies concerning the porous graphite (carbon) structures used for the chlorine electrode, and operation in the flow-through mode. A single-cell battery has given 150 charge-discharge cycles without degradation of the electrode, while performance showed a slight improvement. These results were interpreted to show an extremely stable electrode capable of cycling as required in a vehicular type battery.

Fuel Cells

Fuel cell activity today may seem more directed toward substation electric utility plants such as the new Pratt & Whitney program for nine utility companies with a goal to deliver commercial units by 1978. Nevertheless, the use of a fuel cell was demonstrated in a hybrid (battery) fuel cell powered vehicle, and the results described after one year's operation.[19] Lead-acid batteries were used for peak power, while the fuel cell provided high capacity in a vehicle fitted for operation on public streets. A typical energy density of 50 whr/lb (110 whr/kg) is shown in Figure 4. A typical value for the power density is 10 w/lb (22 w/kg).

As the hydrogen economy gets more notice and more efficient methods of storing hydrogen are devised (e.g., as metal hydrides), new impetus for the use of fuel cells in propulsion applications could result. However, no fuel cells for propulsion were described in the 1972 Status Report[20] on Fuel Cells issued by the Army which has funded fuel cell propulsion in the past.

Experimental Batteries

Lithium-Organic

These batteries have the inherent characteristic of organic electrolytes that are 10 to 50 times less conductive than those for the aqueous batteries. Nevertheless, such organic electrolytes have been developed for use with reactive metals like lithium and a copper halide positive electrode. Unresolved problems include difficulty with the lithium electrode during recharging that is analogous to the zinc electrode problem. Up to 100 to 200 cycles are attained for such systems, but the reasons for low rates of charge and discharge do not appear to be established. Performance at 75 F (24 C) is reported[illegible] at 134 to 164 whr/lb (295 to 345 whr/kg) for a "D" size lithium organic cell at the 50 and 500 hour rate, respectively. Such a battery operates at temperatures as low as -40 F (-40 C), which is the outstanding characteristic of such cells. Reported power densities are only in the range of 38 to 71 w/lb (84 to 156 w/kg).

Lithium-Chlorine

These high temperature batteries are in the advanced experimental stage.[illegible] Techniques such as absorbing the gas on porous carbon electrodes have been devised to avoid handling gaseous chlorine. Single cells have been built and life tested for over a thousand hours, but the best energy density reported for a sealed up cell is about 37 whr/lb (81 whr/kg).

Argonne National Laboratory Report No. ANL-7958 (March, 1973), Appendix B.

[illegible] *"Current Developments in the Sodium-Sulfur Battery", J.D. Bush, Proceedings of the Symposium on Batteries for Traction and Propulsion (March 7-8, 1972), Columbus, Ohio, p 200.*

[illegible] *"Stable, High Energy Nonaqueous Electrolyte Lithium Batteries", M. Eisenberg and K. Wong, Proceedings of the Eighth Intersociety Energy Conversion Engineering Conference (August, 1973), p 58.*

[illegible] *Argonne National Laboratory Report No. ANL-7958 (March, 1973), Appendix B.*

[illegible] *"Batteries for Practical Electric Cars", P.C. Symons, International Automotive Engineering Congress, Detroit, Michigan, Society of Automotive Engineers (January 8-12, 1973), Publication No. 730253.*

[illegible] *"The Zinc-Chloride Battery - The Missing Link to a Practical Electric Car", C.J. Amato, ibid., Publication No. 730248.*

[illegible] *"Chlorine Electrodes in the Zinc-Chlorine Battery System", P.C. Symons and P. Carr, Proceedings of the Eighth Intersociety Energy Conversion Engineering Conference (August, 1973), Philadelphia, Pennsylvania, p 72.*

[19] *"City Car with Hydrogen-Air Cell/Lead Battery", K.V. Kordesch, Proceedings of the Sixth Intersociety Energy Conversion Engineering Conference (August, 1971), p 103.*

[20] *"Seventh Status Report on Fuel Cells" (October, 1972), U.S. Army Mobility Equipment Research and Development Center, Ft. Belvoir, Virginia, Edited by James R. Huff.*

Lithium-Water

A cell has recently been announced[14] for producing electricity from an alkali metal like lithium, and water with a direct, controlled combination of the reactants. The cell requires neither membranes, alloys (amalgams), nor separators. Energy efficiency is expressed in terms of the weight of lithium with achieved energy densities as high as 1600 whr/lb of lithium (3520 whr/kg lithium). For this reason, it is not shown in Figure 4. The results of two years of continuous operation of cells show no signs of deterioration or loss of capacity. The system is expected to be capable of up to 100 whr/lb (220 whr/kg), with maximum power density of 90 w/lb (198 w/kg).

The cell is continuing under development for both military and commercial applications, but is perhaps too early to comment on its potential in the marketplace as a competing power package. If considered for electric cars, water would have to be carried as a fuel unless a water recycling system could be developed. Also, it would appear that a mechanical recharge is required for the lithium electrode.

Discussion

Inspection of Figures 6 and 7 shows that the battery systems discussed herein cover a wide range of specified energy and power densities. In general, those batteries which have reached a relatively advanced state of development, and have matching manufacturing capacity fall in the low range of energy and power densities. When the performance envelopes detailed in Figure 3 are superimposed on Figure 6, then it is readily apperent that the developed batteries are really only suitable for stop-gap measures for low rate applications. This becomes more readily apparent from Figure 7. For high rate applications, all the batteries capable of providing high power and energy densities are still under development, e.g., sodium-sulfur, lithium-sulfur, zinc-chlorine, and lithium-chlorine batteries. These batteries must reach an improved level of development to meet the proposed performance requirements for electric vehicles having a high discharge rate capability for acceptable acceleration and hill climbing performance.

Figure 8 shows data on the speed and range of various electric vehicles as reported by the manufacturers. The vehicles span a range of applications, and therefore differ widely in weight and size, and should not be compared directly. The results illustrate that at speeds of about 40 to 50 mph (64 to 80 kmph), the travel distance is in the range of less than 100 miles (160 km) and closer to 50 miles (80 km) for vehicles propelled by lead-acid batteries. The Chevrolet Vega was powered by a zinc-chlorine battery. The Vega data point is based on a single performance of 76 laps on a 2-mile course at 50 mph (80 kmph), and would appear very promising. However, performance is not reported that would simulate urban driving involving charge-discharge cycling of the battery. The three-wheeled, motorcycle type vehicle was powered by silver-zinc batteries, and completed a 150 mile (240 km) round trip at speeds of 30 to 35 mph (48 to 56 kmph) without recharging.

So far, it has been inferred that the vehicles discussed have been powered by an all electric propulsion system. This, of course, imposes conflicting requirements on the source of electric propulsion. On the one hand, there are the energy/power requirements for steady vehicle operation (low rate applications) which some batteries can meet. On the other hand, there are the requirements for high rate power deliveries, such as needed for acceleration and hill climbing. In conventional battery technology, either one or the other constraints are taken for the design parameters, and then trade-offs are made to make the battery more suitable for a particular application. However, a compromise solution is always obtained, and it is for this reason that there has been much discussion about hybrid electric vehicles - whether electric-electric, or otherwise. One energy source is designed for low rate applications, the other for high rate applications.[15] The resulting system then is better able to meet the design specifications laid down for the various categories of electric vehicle envisaged, as shown in Figure 3. This type of hybrid solution to the propulsive requirements, of course, results in a much greater choice of battery systems being available for application to electric vehicles.

It was mentioned earlier that because of the fuel shortage, emphasis is beginning to shift to alternative means of supplying energy to consumers. One approach is to use secondary batteries to store cheap, off-peak electricity for subsequent delivery during peak delivery periods. This mode of battery operation is easier to meet than the vehicle propulsion mode. Federal monies in large amounts are now being invested in developing battery systems for energy storage, particularly for metal-chalcogen systems, and interest is also growing in using reversible fuel cells, or reversible water electrolyzers for such applications. The result of all this activity can only be beneficial to the electric vehicle program, because at first glance, any battery system suitable for energy storage could be adopted for propulsive applications. Thus, the technology developed during the energy storage (or hydrogen economy) programs can only benefit the development of improved electric vehicle batteries.

In summary, many candidate battery systems have been discussed in detail in this paper. Performance data for electric vehicles powered by lead-acid and zinc-chlorine batteries are summarized in Figure 8. The estimated present state of development of other proposed battery systems is shown in Figure 5. For near-term applications (1975-1980), lead-acid batteries appear to be the major contender. For mid-term applications (1980-1990), the nickel-zinc, zinc-chlorine, and zinc-air batteries could reach a satisfactory state of development. However, in the long term, say in the period of 1980-2000, in order to meet the performance requirements for some of the types of electric vehicles considered, additional development work on battery systems such as lithium-sulfur, sodium-sulfur, and lithium-chlorine, needs to be done.

In the meantime, all the electric vehicles presently on the road, whether commercial or prototype passenger vehicles, continue to increase our data base, and provide useful information on performance and costs, and on integrated system design and manufacture.

[14] *"The Lockheed Power Cell", H.J. Halberstadt, Proceedings of the Eighth Intersociety Energy Conversion Engineering Conference (August, 1973), p 63.*

[15] *"City Car with Hydrogen-Air Cell/Lead Battery", K.V. Kordesch, Proceedings of the Sixth Intersociety Energy Conversion Engineering Conference (August, 1971), p 103.*

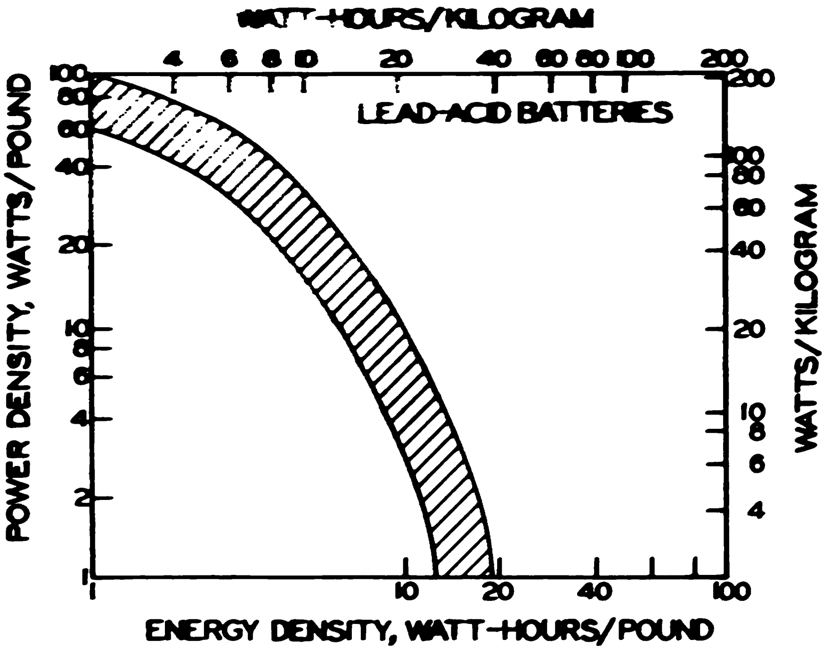


FIGURE 1. RELATIONSHIP OF SPECIFIC ENERGY DENSITY TO SPECIFIC POWER FOR LEAD-ACID BATTERIES.

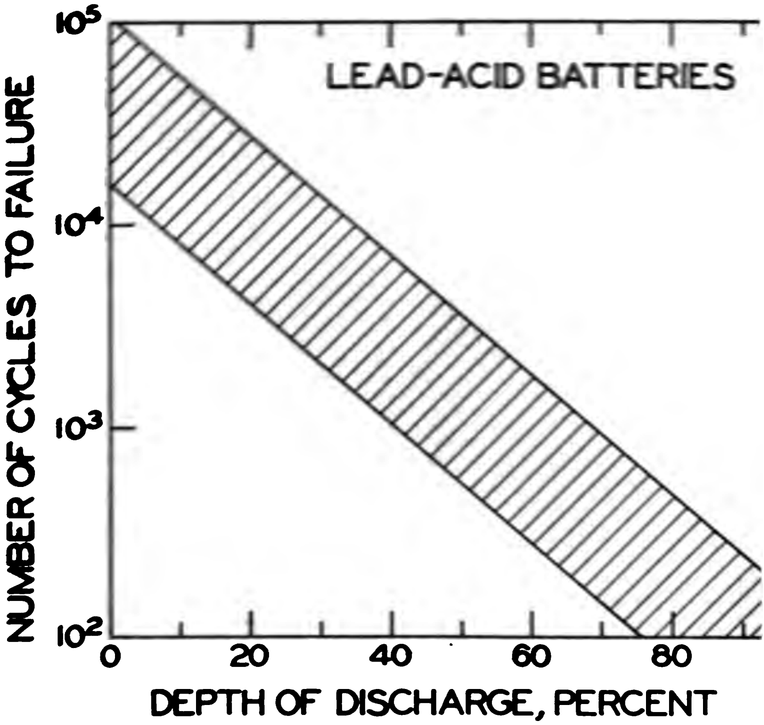


FIGURE 2. RELATIONSHIP OF CYCLE LIFE TO DEPTH OF DISCHARGE FOR LEAD-ACID BATTER

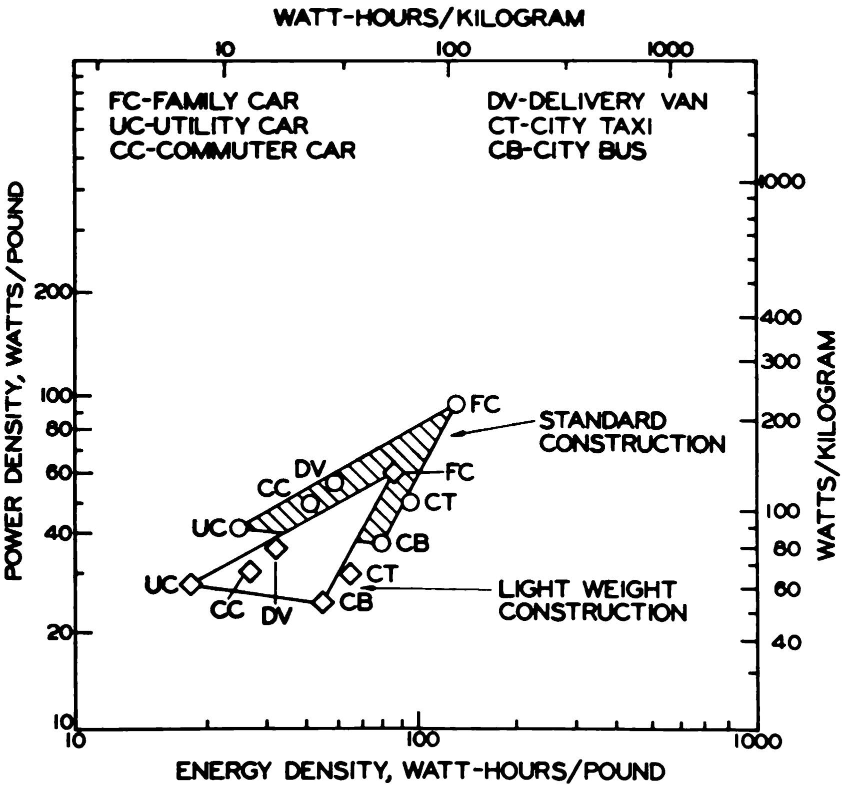
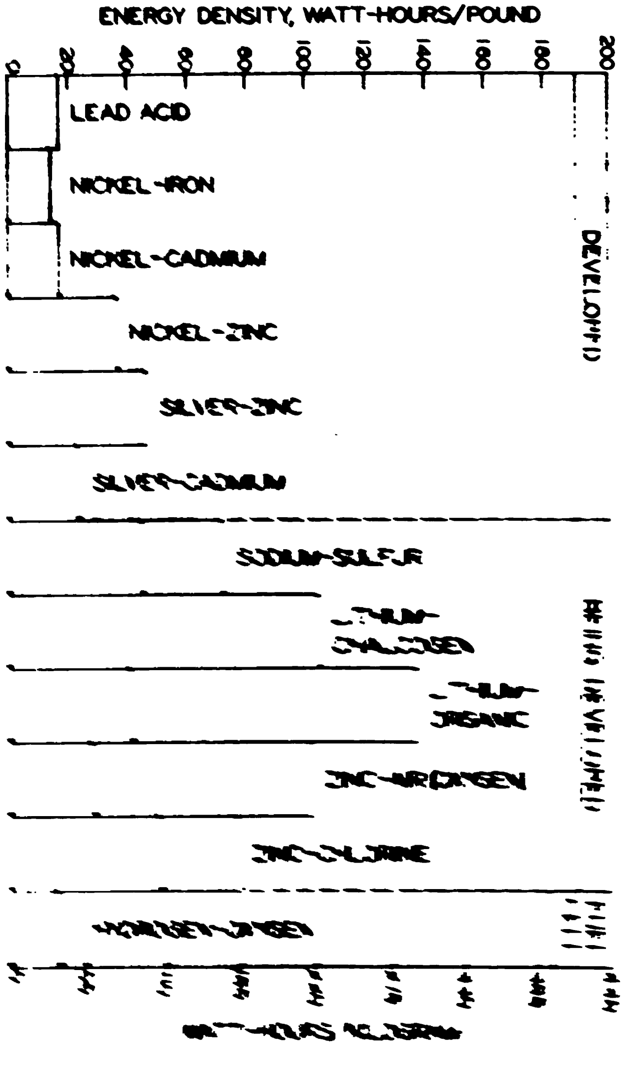


FIGURE 3. ESTIMATED PERFORMANCE REQUIREMENTS FOR TYPICAL ELECTRIC VEHICLES.


ENERGY DENSITY, WATT-HOURS/POUND
LEAD ACID
NICKEL-IRON
NICKEL-CADMIUM
NICKEL-ZINC

ANODE MATERIALS/REACTANTS

CATHODE MATERIALS/REACTANTS

	Pb	Cd	Fe	Zn	H	Li	Na	Al	Mg	Ag	Ca
PbO_2	A										
NiOOH		D	D	D	E						
AIR O	E	E	E	P	P		E	E	E		E
AgO		D		D	E						
S*						P	P				
Cl**				P		E		E	E	E	
$CuCl_2$						E					
CuF_2						E					
CuS_2						E					

FIGURE 5. DEVELOPMENT STATUS OF BATTERIES IN CONTENTION FOR ELECTRIC PROPULSION SYSTEMS.
* Including other chalcogens and mixtures of same.
** Including other halides.
A = Available system (for typical achieved energy densities, see Figure 4).
D = Relatively developed system (for typical achieved energy densities, see Figure 4).
P = Prototype system (for typical achieved energy densities, see Figure 4).
E = Experimental system.

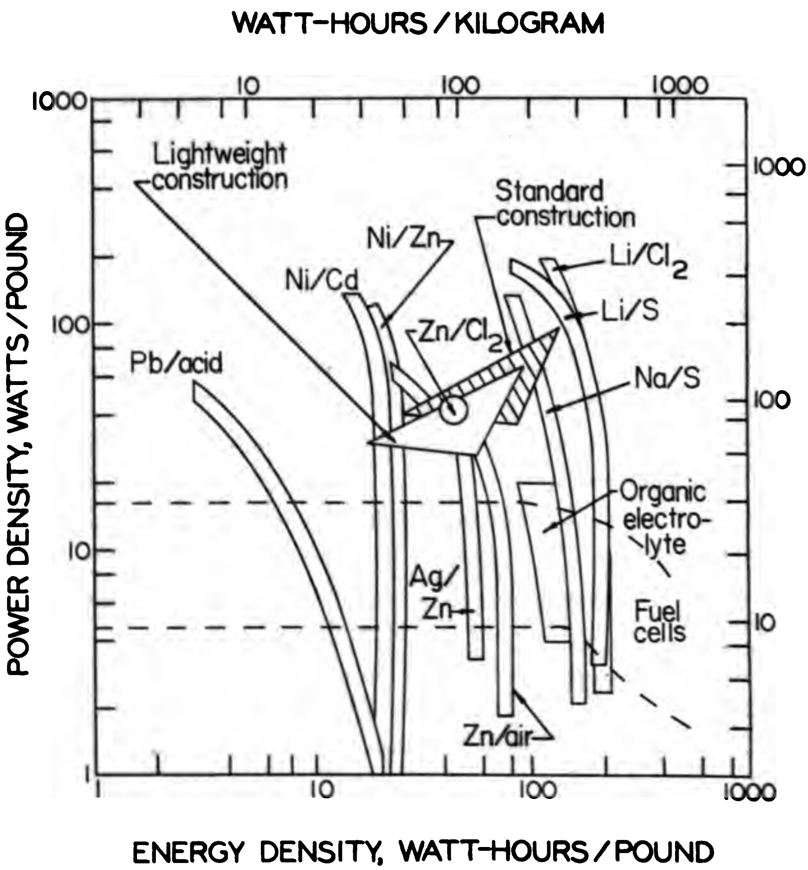


FIGURE 6. RELATIONSHIP OF SPECIFIC ENERGY DENSITY TO SPECIFIC POWER DENSITY FOR SELECTED BATTERIES AND SUGGESTED PERFORMANCE ENVELOPES FOR ELECTRIC VEHICLES.

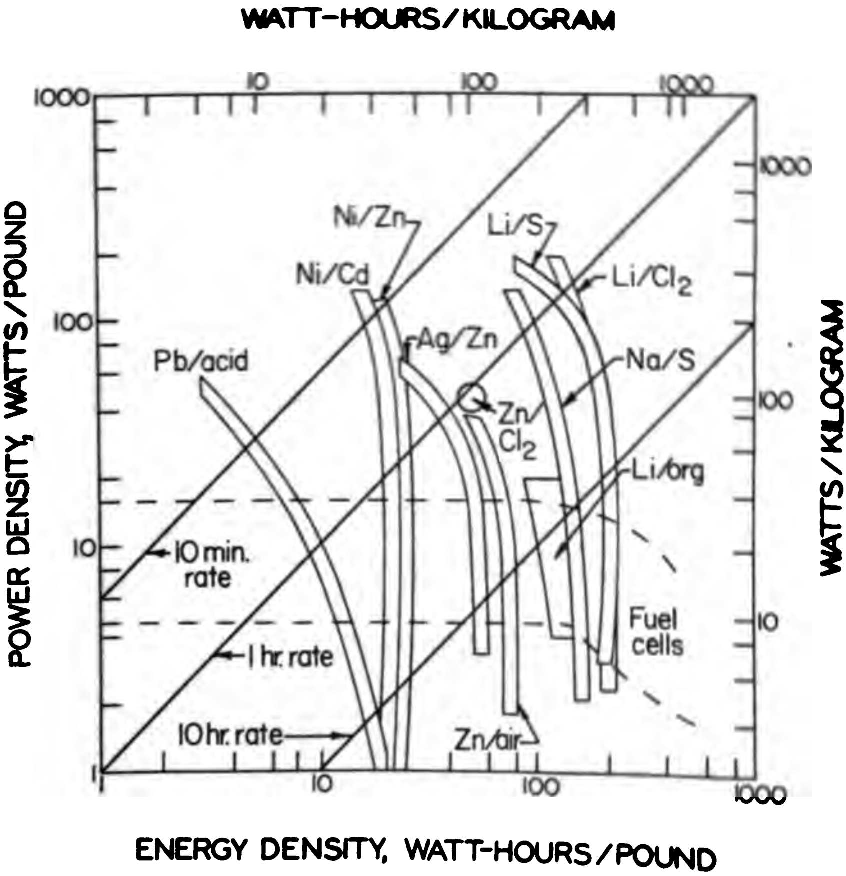


FIGURE 7. RELATIONSHIP OF HOURLY RATE OF DISCHARGE TO ENERGY AND POWER DENSITIES FOR CANDIDATE ELECTRIC VEHICLE BATTERIES.

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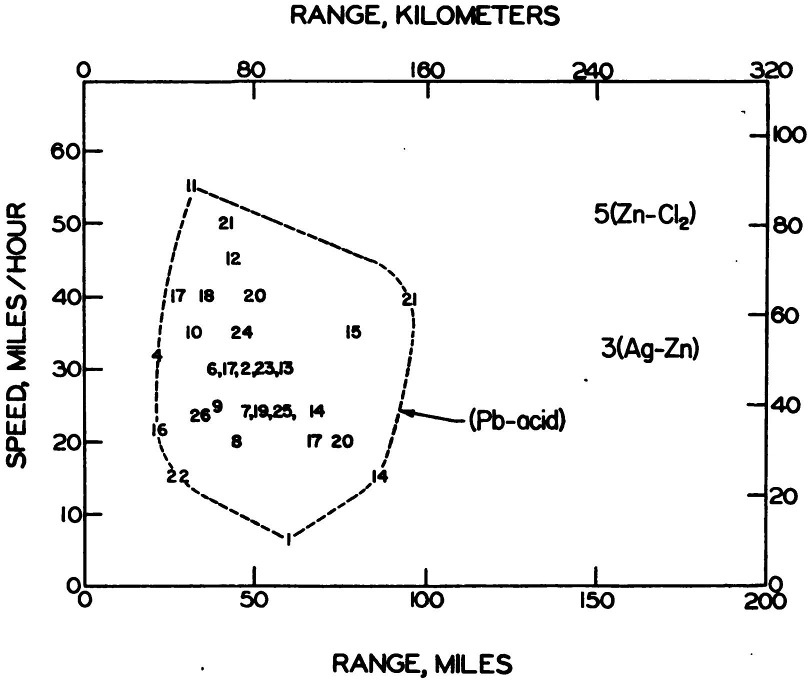

FIGURE 8. DATA ON SPEED AND RANGE FOR ELECTRIC VEHICLES REPORTED BY MANUFACTURERS.

1. Branson Electra-Boat
2. Auranthetic Electric Motorcycle
3. Eagle-Picher (3-wheel) Motorcycle
4. Corbin Electric Motorcycle
5. Chevrolet Vega Car
6. Sebring-Vanguard Sport Coupe
7. Sebring-Vanguard Utility Car
8. Electra-King Car
9. TSL Resort Islander
10. TSL Commuter Islander
11. TSL Sports Islander
12. Enfield Utility Car (UK)
13. Electric Car (Sweden)
14. Electric Car (Japan)
15. Marcos Car (UK)
16. EVI Utility Car
17. Battronic Van
18. TSL Utility Van
19. Electric Delivery Van
20. Prototype Urban Van
21. Copper Electric Van, III
22. Delivery Van (UK)
23. Volkswagen Van (Germany)
24. Tork-Link Electrobus
25. Morrison Electric Bus (UK)
26. Crompton Electricars Bus (UK)

Materials Problems Associated With Electric Vehicle Batteries

(By Eric W. Brooman and John E. Clifford, Battelle's Columbus Laboratories, Columbus, Ohio)

ABSTRACT

Materials problems exist with both the active and the inactive battery components. These problems are identified for the battery systems in contention for electric vehicle propulsion, and fall under the general categories of (1) low ratio of practical to theoretical energy density, (2) active component capacity losses, (3) corrosion of inactive components, (4) inadequate separator materials, (5) unavailability of hermetic seals, and (6) restricted availability or high cost of certain materials. Current research to solve some of these materials problems is outlined.

1. INTRODUCTION

Electric vehicles are an attractive alternative to internal combustion engine vehicles. Two important factors in their favor are the absence of significant noise and atmospheric pollution, and the use of night-time electric power for recharging which acts as a load-levelling means. Why then are there not more electric vehicles on the road? Part of the problem is cost. The components needed for the controls and drive train are not produced in large quantities at the present time, hence are expensive. Another part of the problem is the energy source—the batteries. Those batteries which are available and reasonably priced cannot give the power and/or energy densities which would make the vehicles competitive with internal combustion engine (IC) automobiles. Those batteries under development which are capable of higher power-energy densities are very expensive. Batteries now available and those being developed have materials problems which will be discussed subsequently.

Figure 1 shows battery systems which have been considered for electric vehicle propulsion applications. A battery essentially consists of active components and inactive components. The active components are the anode materials and the cathode materials, and in some instances the electrolyte which provides an ionic conduction path between the two. The inactive components include separators (electrical insulation between anodes and cathodes), current collectors, terminals and containers. Figure 1 shows, for example, that in a silver-zinc battery the anode is zinc metal and the cathode is silver oxide. These are the active components, and they have a theoretical energy density. However, when the active materials are packaged to obtain electricity for practical applications, the added weight of the inactive components, plus the electrical inefficiency of operating the anode and cathode materials under nonequilibrium conditions, drastically reduces the obtained energy and power densities. Typically, values of about 1/5 the theoretical are obtained. Thus, one problem with all batteries is to select the packaging and structural materials to minimize the overall weight and volume, and hence yield energy and power densities closer to the theoretical values.

Various federal agencies have authorized studies to determine the typically desirable electrical battery characteristics for various types of vehicles. These desirable characteristics are shown in Figure 2 for vehicles of standard construction and of lightweight construction, while Figure 3 shows how some of the battery systems in Figure 1 compare with the performance requirements. The following section describes some of the materials problems associated with those batteries most likely to meet these requirements.

2. MATERIALS PROBLEMS IN BATTERIES

2.1 *Lead-acid batteries*

Lead-acid batteries of the heavy duty and golf-cart types are mass produced, hence readily available and relatively inexpensive. However, they fall short of the power and energy density requirements (See Figure 3) for competitive performance with IC automobiles. Nevertheless, these batteries are currently used in a wide range of vehicles giving a performance of about 30–50 mph (50 to 80 kmph) top speed and a range of 30 to 50 miles (50 to 80 kilometers) between charges. Battery cost and useful life (number of charge/discharge [illegible] es to failure) are usually inversely related, hence the low cost lead-acid batte[illegible]

a long cycle life, as Table 1 shows, which helps to offset their relatively poor performance.

Because lead-acid batteries are by far the most widely used power sources in electric vehicles, these batteries will be discussed in more detail than some of the other power sources.

The major problems with lead-acid batteries are grid corrosion and shedding. Conventional batteries use a Pb-Sb alloy for cast grids to support the active materials, the antimony acting as a hardening agent. Unfortunately during use the grids corrode because of the local Pb-Sb galvanic couples set up, and the antimony migrates from the positive to the negative plates. This migration causes the negatives to self-discharge, with a resulting detrimental effect on performance. Considering also that antimony is costly and scarce, this is a highly undesirable alloy. The special types of battery developed for electric vehicles overcome the corrosion problem to a large extent by casting the grids from a Pb-Ca-Sn alloy. Longer life batteries result, and less hydrogen is evolved due to the corrosion process. Another approach has been to develop noncast grids so that detrimental alloying additions do not have to be added to improve strength or fluidity for casting. Pure lead grids would solve the corrosion problem, but unfortunately their mechanical strength is insufficient to ensure dimensional stability in use. Dispersion strengthening with inert materials (such as glass fibers) is being evaluated to allow noncorroding grid materials to be used. With emphasis often being placed on high power (high discharge rate) applications, making the plates as thin as possible is an advantage but dimensional stability becomes relatively more important.

Improvements in grid materials are, therefore, a highly desirable development. Recent research sponsored by ILZRO has shown that increasing the thickness of the active material over the grids ("over-pasting") does not provide total grid protection against corrosion, however the overpasting can keep the protective corrosion products intact on the grids for a longer period of time, thus slowing down the grid corrosion processes.

R&D is continuing in the areas of increasing the cycle life and utilization of the active materials. The use of glass fiber envelopes around the positive plates appears to be a satisfactory stop-gap measure to prevent shedding (active material falling from the plate in service giving rise to a sludge at the bottom of the cell). Studies have been made of the use of paste additives, such as barium sulfate and lignin, to extend the life of the negative plates. These "expanders" apparently restrict the size of the lead particles which grow during charge, and also promote a more open electrode surface structure during discharge. Electrochemical sintering—the coalescing of small particles of high surface area to give large particles of low surface area during charge-discharge cycling is a problem not unique to the lead-acid battery system. Similar "aging" or "memory" effects are found in electrodes of aerospace alkaline cells and fuel cells also.

While progress is slow in improving the efficiency of utilization of the active materials, efforts have been made to improve power and energy density ratings by reducing overall battery weight. New grid designs permit higher currents and more uniform current density distribution giving longer life with reduced weight. Internal connector paths have been altered to reduce weight also, especially in the plastic-cased monobloc type cells. The new plastic cases are thinner, hence for a given outside dimension more plates can be packed in, giving a higher capacity battery. However, the polypropylene used for the cases is now in short supply because of the recent petroleum crisis. A need exists for the development of an alternative material.

2.2. Alkaline batteries

Nickel-cadmium, nickel-iron, nickel-zinc and silver-zinc batteries contain alkaline electrolytes. They are all more expensive battery systems than the lead-acid system, however, their electrical performance is significantly higher than that of lead-acid batteries as Figure 3 shows.

There is an insufficient supply of cadmium to sustain a large market for nickel-cadmium batteries even if the battery price were not an obstacle to widespread usage. The nickel-cadmium battery system has been proven in many [illegible] applications to have an extremely long cycle life (Table 2), [illegible] some materials problems—reactions which occur between th[illegible] and other cell components, such as separators. In nickel-cadm[illegible] batteries oxidation of the separator can occur leading to [illegible] electrolyte resulting in a lower cell voltage and loss of po[illegible]

city. In nickel-cadmium or nickel-zinc batteries it is thus important to exclude all oxidizable materials so that these parasitic reactions cannot occur. Separator development work is continuing, and care is being exerted to control manufacturing processes to minimize undesirable contaminants.

Another material problem lies in the fabrication of suitable metal-ceramic seals to hermetically seal the batteries, thus preventing CO_2 pickup by the electrolyte, which is detrimental. One of the major causes of failure in nickel-cadmium batteries results because of electrolyte leakage around the seal(s).

Improvements in the nickel-iron system have significantly increased the electrical performance to above 22 watt-hr/lb and about 40 watts/lb, but this is still below the requirements set out in Figure 2. The disadvantage with this system is that hydrogen is evolved on charge and must be removed by some means. In nickel-zinc batteries nonsintered nickel electrodes have been developed, containing about half the nickel, to cut down on cost, but a problem still exists with the zinc electrode. Zinc electrodes in any battery system cause problems because of uneven distribution ("shape change" or "slumping") on cycling which leads to lower electrical efficiency and cycle life, and under certain conditions zinc dendrites may form and grow through the separator(s) causing shorting. Developments in inorganic separators have allowed zinc migration and shorting to be significantly reduced.

In silver-zinc batteries the problems with the zinc electrode are just as severe, and a relatively short cycle life is also obtained. Cellulosic separators have been used in the past to slow down the migration of the active materials away from the electrode surfaces. However, in high-rate applications the electrolyte temperature may reach 200F (93C) which causes rapid separator degradation. The technology developed for heat sterilizable aerospace cells might be considered to solve this separator problem, however, it is doubtful whether large scale usage of silver-zinc batteries will materialize because of the cost of silver. Research is still continuing, nevertheless, to obtain a better understanding of the reasons for shape change and shorting. It has been shown that the nonuniform resistance of the silver grid support (current collector) causes a distribution of current density during operation which varies widely over the electrode. Zinc tends to dissolve faster at the high current density areas at the top and sides of the electrodes, and redeposit at the lower current density areas in a more dense form of lower surface area. Development of a grid that overcomes the uneven current density problem is desirable, and something may be learned from lead-acid battery technology where a similar problem exists.

2.3 *Metal-air batteries*

Metal-air or metal-oxygen batteries are attractive systems because of their high energy densities, and low materials costs. Though many metal-air and metal-oxygen systems have been investigated, the most developed system is the zinc-air battery. Of the other candidate metals beryllium is too costly, and also poisonous; lithium is too costly; aluminum corrodes too rapidly for most applications, as does magnesium, which also gives a sludge in operation; titanium passivates too easily; cadmium has a low efficiency and sodium has to be amalgamated.

Mechanically rechargeable batteries (either by physically replacing the zinc electrodes or by using a recirculation means) have been used in electric vehicles. However, much work is needed before an electrically rechargeable battery with long cycle life is developed. Part of the materials problem is to replace the expensive noble metal electrocatalysts in the air electrode with a cheaper electrocatalyst. At the high recharge rates extremely corrosive conditions exist at the air electrode because of oxygen evolution. Carbon, which is a cheap, satisfactory electrode material for many applications cannot withstand these highly oxidising conditions. Even platinum and palladium dissolution occurs at the high anodic potentials at the electrodes. Two and three layered electrodes have been developed to try and overcome th[illegible]oblem. For example, a nickel layer/gold-black/porous Teflon la[illegible]hereby the nickel serves as the chargi[illegible]n gold), the gold-black layer serv[illegible]us Teflon is used as a support [illegible]ilar configurations, bu[illegible]eased fabrication[illegible]

Th[illegible]lectrode-short[illegible] with the zi[illegible]shape change[illegible]oped

and evaluated. Also a partially well-graded sintered nickel layer has been used as a physical barrier between layers of conventional separator material. The ideal separator material would have a high electronic resistivity but a low resistance to ion transport, be wettable and retain the electrolyte, would be oxidation resistant and would be a barrier for oxygen transport and zinc dendrite formation. At present no single material can fulfil all these requirements. To prevent passivation of the zinc electrodes during charging they have been wrapped with a polyamide felt wick which dips into an electrolyte reservoir in the bottom of the cell. Encapsulation with an acrylic acid grafted polyethylene separator has been tried to reduce oxygen migration to the zinc electrode. However the problem of capacity loss at the zinc electrode is still virtually unsolved. Various approaches have been tried, such as using air or oxygen electrodes smaller than the zinc electrodes to improve the current density distribution, or using plastic honeycomb supports to physically try and prevent the migration of the dissolving zinc. Some of these approaches have shown promise, but much remains to be done to satisfactorily resolve the problem of shape change on discharge and dendrite formation (penetration) on recharge.

2.4 Other metal-gas batteries

Zinc-bromine batteries show promise of a high energy density but suffer from a very high self-discharge rate and consequently the system is not a serious contender for propulsion applications until a suitable separator material has been developed. Zinc dendrite formation is apparently not a problem because of rapid redissolution of the zinc in the electrolyte. Zinc-chlorine batteries are perhaps the most developed metal-gas systems. The chlorine storage problem has been overcome in one design by converting the chlorine into refrigerated chlorine hydrate, a relatively [illegible] material to handle. Recent studies concern improving the porous graphite structures used for the chlorine electrode.

Nickel-hydrogen and silver-hydrogen batteries are being developed as successors for the alkaline batteries described earlier, which have lower practical energy and power densities. With both metal-hydrogen systems there is also the problem of a high self-discharge rate due to the mobility of the hydrogen. The hydrogen gas also has to be stored under pressure or immobilised as a hydride, which adds to the overall system weight and hence lowers the practical energy density which could be obtained. Both nickel and silver are relatively expensive positive materials and at the present time an expensive platinum-black is needed for the negatives. Thus at the present time the nickel-hydrogen system [illegible] about 1500 \$ [illegible]. By substitution of less expensive materials [illegible] — the cost might drop to about 150 \$ [illegible]. Considerable scope in the area of materials development exists for these battery systems.

2.5 High temperature systems

Sodium-sulfur and lithium-sulfur batteries are the most [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible]

While sodium and sulfur are relatively cheap materials and attractive from an electrochemical [illegible] their high temperature operation does result in a [illegible] — sodium [illegible] about 1 [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible]

[illegible] with sodium-sulfur [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible]

to contain liquid sodium in nuclear applications; hopefully, this technology can be transferred. Conditions at the cathode are less corrosive, so there is hope for lower cost materials for the cathode container. Any oxygen present in the cell will increase the rate of corrosion; therefore, during the assembly of cells and batteries, care should be taken to exclude all oxygen.

With lithium-sulfur batteries, the materials problems are similar to those for the sodium-sulfur systems. The molten lithium attacks the cell components, but recent developments which include the use of a lithium-aluminum alloy anode, and a metal wire screen enclosure have lessened this problem. The greater dimensional integrity has improved the cycle life. Sulfur loss at the cathode is another problem area. One solution seeks to minimize sulfur diffusion by alloying or by using metal sulfide electrodes, but the electrical performance is reduced. Another attempt at solving this problem is to use a sulfur-arsenic-carbon (semi-solid) electrode. The arsenic addition tends to retain the sulfur, while the carbon improves electrode rigidity and increases electrode conductivity. If the charging voltage is kept below 2.7 volts, then the expanded molybdenum mesh grids (current collectors) used in many designs are corrosion resistant. Above this voltage corrosion occurs, and for prolonged operation a substitute material having a better corrosion resistance would be needed.

3. SUMMARY AND CONCLUSIONS

Battery engineers have chosen many electrochemical couples capable in theory of giving high energy densities at a reasonable cost. These engineers are continually striving to improve the performance of these couples in actual practice by first trying to understand the mechanisms of the reactions which occur, then by controlling these reactions in the most desirable manner, and preventing as far as possible any detrimental parasitic reactions which affect the battery performance. Concurrent with this effort materials engineers play an important role in containing the active materials and producing a practical product acceptable to the general public. Battery and materials engineers must work hand in hand to overcome the many problems which arise in producing a high energy, high power density battery for electric vehicle propulsion applications.

Although specific materials problems with a wide range of batteries have been described, the general problem areas are similar for each battery type. These problem areas may be summarized as follows:

(1) Low ratio of practical to theoretical energy density
(2) Active component capacity losses
(3) Corrosion of inactive components
(4) Inadequate separator materials
(5) Unavailability of adequate hermetic seals
(6) Restricted availability or high cost of certain materials.

The theoretical energy density of electro-chemical couples can never be realised when cells or batteries constructed, because the inactive components (container grids, terminals, connectors, and so on) add weight to the overall system, but do not contribute to the delivered energy. However, by careful design and selection of materials the inactive component weight contribution can be minimised.

Active component (electrode material) capacity losses may be direct or indirect. With inadequate separation of the anode and cathode materials self-discharge may occur very rapidly by a direct process, especially if the cathode material is a gas. Loss of capacity is also possible by indirect means if oxidisable materials are present to react with the active electrode materials. Thus, the trend has been to move away from organic separator materials, which may be oxidized by the positive electrodes, causing the latter to lose capacity and possibly causing the electrolyte to become carbonated. Inorganic separators are now favored for many battery applications. Another cause for capacity loss is often associated with redistribution of the anode material during charge/discharge cycling. This is [illegible] true for zinc electrodes, and electrochemical, chemical or mech[illegible] [illegible] to [illegible] this redistribution or shape change. Imp[illegible] [illegible]ver the electrode by improved gri[illegible] [illegible] extreme, during charging den[illegible] [illegible]ll shorting. Improved sep[illegible] [illegible] means of control.

[illegible] [illegible]eserve the struc[illegible] [illegible] of the active

materials, such as molten sodium and lithium and chlorine for example, are extremely corrosive, and materials presently used tend to be very expensive and/or relatively heavy. Scope exists for improvements in this area of materials applications.

A leak-free, low cost, reliable hermetic seal, either metal-ceramic or ceramic-ceramic, does not exist at the present time. An improved seal would enable cells with much longer life to be constructed. If the active materials balance is correctly formulated then excessive gassing should not result and venting should not be required. A hermetically sealed battery would then mean that there would be greater freedom in location on the vehicle.

In conclusion, while battery engineers concern themselves with the electrochemical aspects of battery performance, a whole spectrum of materials problems exist waiting for solutions from the materials engineers.

4. BIOGRAPHIES

Dr. Eric W. Brooman, Staff Metallurgist, Electrochemical Engineering Technology Section, has been actively involved in a wide variety of research programs on batteries including such endeavors as the development of new alloys for primary battery systems; the thermodynamics of secondary battery systems, especially heat transfer and thermophysical property data determinations and analysis of failure mechanisms and development of relevant accelerated life tests. He recently led a group which had the responsibility for planning, designing, and construction of a plant to manufacture lead-acid batteries in a developing country. His current interests include batteries for electric vehicle propulsion and off-peak energy storage.

J. E. Clifford, Associate Manager, Electrochemical Engineering Technology Section, has conducted and directed research and development programs on electrochemical energy storage systems covering primary and secondary batteries, fuel cells, and water electrolysis cells. Three of his patents are on batteries—a lead-acid battery, a lead-titanium battery, and an electrically rechargeable zinc-air battery. His research has covered failure mechanisms; thermodynamics and kinetics of battery electrode reactions; comparative application studies of various batteries; development of new batteries; and the design of practical battery systems for optimum size, weight, and energy output. His current interests also include batteries for electric vehicle applications, and off-peak energy storage.

TABLE 1.—PERFORMANCE PARAMETERS OF BATTERIES IN CONTENTION FOR ELECTRIC VEHICLE PROPULSION

Battery system	Specific power, watts per pound or specific energy watt hour per pound[1]		Initial cost[2]		Estimated cycle life at [illegible] percent discharge
	Achieved	Expected	Per pound	Per kilowatt-hour	
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	

[1] [illegible]

[2] [illegible]

Anode Materials/Reactants

Cathode Materials/Reactants	Pb	Cd	Fe	Zn	H	Li	Na	Al	Mg	[illegible]	[illegible]
PbO_2	A										
NiOOH		D	D	D	E						
Air O_2	E	E	E	P	P		E	E	E		E
AgO		D		D	E						
S*						P	P				
Cl**				P		E		E	E	E	
$CuCl_2$						E					
CuF_2						E					
CuS_2						E					

* Including other chalcogens and mixtures of same

** Including other halides

A = Available system (for typically achieved energy densities, see Figure 3)

D = Relatively developed system (for typically achieved energy densities, see Figure 3)

P = Prototype system (for typically achieved energy densities, see Figure 3)

E = Experimental system.

FIGURE 1.—Development status of batteries considered for electric vehicle propulsion systems.

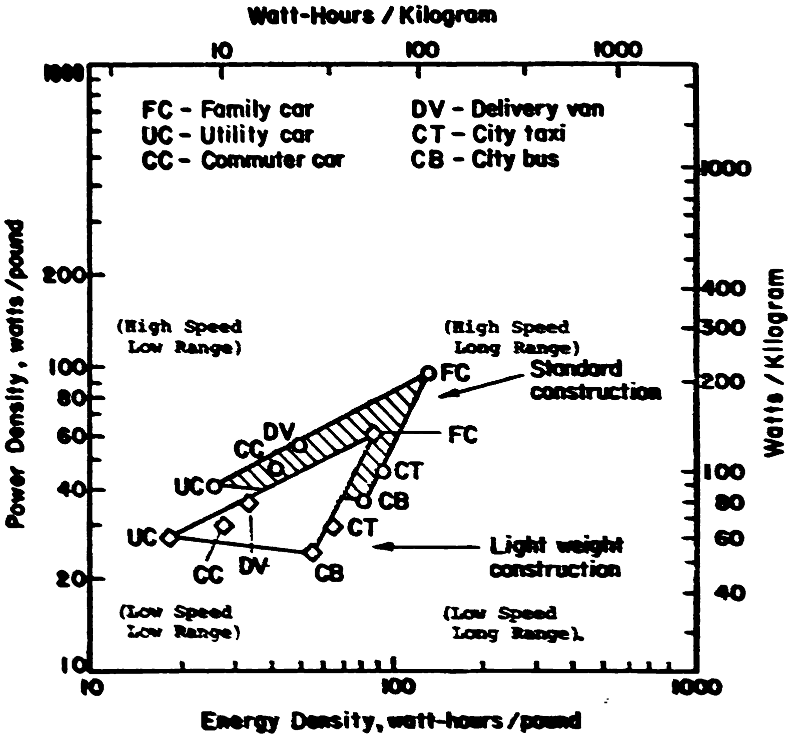

FIGURE 2.—Summary of desirable electrical performance characteristics of batteries for different types of electric vehicles.

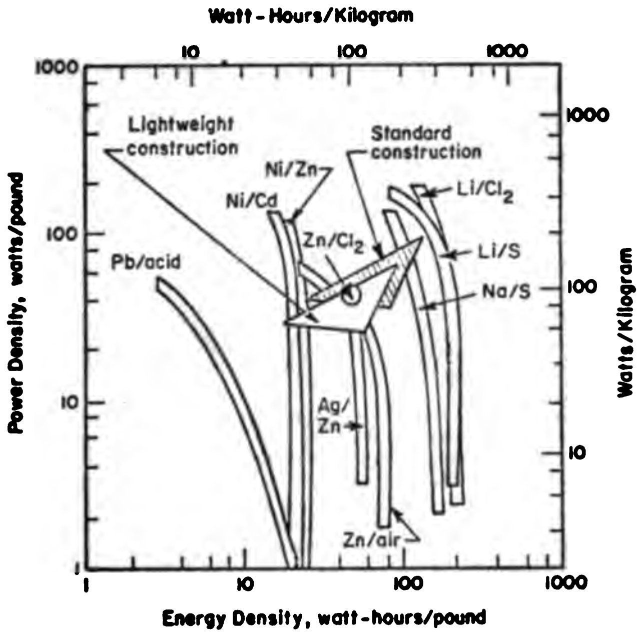

FIGURE 8.—Specific energy density and specific power density for selected batteries and suggested performance envelopes for electric vehicles.

FEDERAL POWER COMMISSION,
Washington, October 3, 1975.

Hon. FRANK E. MOSS,
Chairman, Subcommittee for Consumers, Committee on Commerce, U.S. Senate, Dirksen Senate Office Building, Washington, D.C.

DEAR MR. CHAIRMAN: I am writing in response to your September 29, 1975 request for a Commission response to your questionnaire "on electric vehicles and related matters." The enclosed memoranda from the Commission's Bureau of Power and Office of Energy Systems should be considered as a Commission staff report in response to your questionnaire.

Sincerely,

JOHN N. NASSIKAS, *Chairman.*

Enclosures.

OCTOBER 2, 1975.

Memorandum to: Daniel Goldstein, Assistant General Counsel.
From: Richard F. Hill, Acting Director, Office of Energy Systems.
Subject: Questions relating to S. 1632, the Electric Vehicle Research, Development, and Demonstration Act of 1975.

Office of Energy Systems responses to the subject questions are attached.

RICHARD F. HILL.

Attachment.

RESPONSES TO QUESTIONS: S. 1632 AND H.R. 8800

1. It is estimated that replacement of one million internal-combustion-engine (ICE) motor vehicles with electric vehicles, at technology levels realizable in the early 1980's, could save from six to ten million barrels of crude oil per year, provided the electric energy is generated from a mix of fuels corresponding to overall national projections for the 1980's. Presumably this saving would directly reduce import requirements correspondingly.

One million motor vehicles represents less than 1% of present total automobile registration in the U.S.

This estimate is derived as follows: the vehicles in question are assumed to be passenger automobiles or similar vehicles, such as small delivery trucks. At current (1975) levels of efficiency and with current patterns of use, the average such vehicle consumes energy equivalent to about sixteen barrels of oil per year. Improvements in efficiency may be expected to reduce this to six to nine barrels by the early 1980's. Taking account of refining and distribution efficiencies, this corresponds to from eight to twelve barrels of crude oil. Thus the gross saving from eliminating one million such vehicles would be from eight to twelve million barrels annually.

The replacement electric vehicles would each be expected to consume approximately 6000 KWHR per year (12,000 miles at 2 mi/KWHR). If this electric energy were obtained from oil-burning power plants, the oil required would be about 9.5 barrels per year per vehicle, and there would be a very small net saving in oil, or perhaps a small loss. But in the time periods from 1980 onward, oil is expected to be used for only about 16% of electric generation nationwide. Using this nationwide average proportion, the replacement electric vehicles would thus account for about 1.5 million barrels of oil per million vehicles. Thus the net saving could be from six to ten million barrels.

This estimate is predicated on replacement of "average" vehicles. If high-mileage short-trip vehicles, such as delivery trucks, were assumed, the savings could be greater, perhaps twice as great. But this is a relatively small vehicle class and the ultimate savings are thereby limited.

It should be noted that the electric energy for recharging the electric vehicles will tend to be consumed during off-peak hours, and will be available at relatively low incremental cost. However, since nuclear plants in the early 1980's are expected to be fully base-loaded on a 24-hour basis, the increment of energy for vehicle recharging will have to come from fossil fuels. Whether this will involve mainly oil or mainly coal depends on local and regional and electric system economics and structure.

2. Using the same assumptions as in the response to question 1, the substitution of one million electric vehicles would have a negligible effect on electric utility capacity requirements and corresponding capital requirements. The electric energy needed for the vehicles would total about six billion KWHR, which is less than 0.2% of the projected 1980 generation of 3250 billion KWHR. Since the major part of the electric vehicle load would occur during off-peak hours, the increase in capacity needed would be negligible. Fuel would be consumed to generate the small increment of electric energy, and those environmental effects which are directly related to fuel consumption would experience corresponding small increases.

3. Vehicle-charging load during off-peak hours would tend to increase electric utility capacity factor. The amount of load is so small, however, that the effect on capacity factor (in 1980) would be less than 0.1% per million vehicles, using the assumptions as before, and the additional assumption that all vehicle-charging is done during off-peak hours. The effect on average cost of electric energy would be correspondingly very small.

It should be noted that the energy cost for the electric vehicles is attractive even at current typical residential rates. Assuming 2 miles per KWHR, as before, the energy cost would be (typically) 2¢ to 3¢ per mile, substantially less than for current internal-combustion engine passenger automobiles. If special rates were instituted for off-peak charging, the electric vehicle energy cost would be even less.

4. Substitution of electric cars for IC[illegible] cars will not present a serious [illegible] insofar as water use is concerned, at [illegible] up to the level of [illegible] million vehicles, and may, in fact, [illegible] generally. First it must be re[illegible] tric power generation is ac[illegible]

passed through the plant to provide cooling, and is returned to the natural water body at slightly increased temperature. Since the temperature increase in the natural water body varies with plant load, and since there is evidence that the cyclic temperature variation may be more harmful environmentally than the absolute temperature difference, any increase in off-peak load, such as for electric vehicle charging, may tend to be environmentally favorable.

Actual consumptive use of water for electric vehicle charging would be in proportion to the energy generated, thus one million electric vehicles in 1980 would add less than 0.2% to water consumed by electric utilities.

With respect to water quality, it should be noted that significant quantities of petroleum residues are carried in surface run-off water, eventually finding their way into streams. Some reduction in this effect would result from reduction in the number of ICE vehicles.

OCTOBER 2, 1975.

Memorandum to: Office of the General Counsel.
From: Chief, Bureau of Power.
Subject: Questions concerning S. 1632 and H.R. 8800 submitted by Senator Moss (electric vehicles).

Bureau of Power responses to the subject questions are attached.

T. A. PHILLIPS.

Attachment.

QUESTIONS CONCERNING S. 1632 AND H.R. 8800

Question No. 1. Electric automobiles are assumed to be small commuter models, driven an average of 6500 miles per year, with a energy requirement for recharging batteries that would average 0.5 kilowatt-hours per mile. On this basis each one million vehicles would require an electric energy supply of 3.25 million megawatt-hours per year.

To supply this added amount of energy, the electric power industry would have to consume annually, for each one million vehicles, either an additional 5.85 million barrels of oil or 1.53 million tons of coal, or operate 570 megawatts of additional nuclear capacity.

Based on projections for 1980, the added electric load of one million electric vehicles would represent approximately 0.12 percent of the total electric energy production in that year. Additional nuclear capacity beyond that now planned and under construction cannot be available in 1980, and all scheduled nuclear capacity will be operated at maximum output, even without an added electric vehicle load. Thus, any increase in 1980 electrical demand resulting from electric vehicles will be met by increased consumption of fossil fuels. If the national electric power system was perfectly interconnected and transmission losses were negligible, it would be possible to supply the additional demand using only coal fired capacity, if the coal is available. The incremental coal consumption for one million vehicles, 1.53 million tons, is 0.25 percent of the projected total 1980 coal consumption for electric power of approximately 600 million tons. Since battery charging (or equivalent regeneration of electro-chemical materials) would be done at off-peak hours, no additional coal generating capacity would be needed for such a small energy increase.

Because the transmission system is not perfectly interconnected nor without losses, undoubtedly some of the additional energy would be supplied by oil fired generation in the regions where the vehicles are used. In 1980, generation by oil is projected to be about one-fourth of that of coal and oil combined, so that on a proportionate basis the added load of one million electric vehicles in 1980, assuming no shortage of coal, is likely to be met by the use of 1.15 million tons of coal and 1.46 million barrels of oil. This incremental amount of oil is 0.18 percent of the 800 million barrels of oil projected to be used for electric power in 1980.

The internal combustion engine [illegible] s replaced by the electric vehicles are as-
sumed to be light-weight, limit [illegible] rformance units averaging 30 miles per
gallon in commuter service. Wi [illegible] erage vehicle annual mileage of 6500,
one million [illegible] s would consume approximately 5.16
million [illegible] ning adequate coal supplies, the
effect [illegible] be to reduce gasoline imports
by [illegible] by 1.46 million barrels,
[illegible] llion barrels per year.
[illegible] imports only so long
[illegible] icity demand. How-

ever, the adequacy of coal supply for electric power in 1980 is not entirely clear. The electric power industry demand for coal is projected to increase 50 percent by 1980, a formidable challenge for the coal producers and the transport industry.

For later dates, such as 1990, there is sufficient lead time for construction of additional nuclear plants, and for further expansion of coal production and delivery capabilities, to ensure that practically all of an anticipated increase in electricty demand resultng from electric vehicles would be provided by these two energy sources.

Question No. 2. From the standpoint of equipment utilization, the electric power industry as a whole could readily accept and would welcome a substantial increase in the national annual load factor.

Ten million electric vehicles in 1980 would increase the energy demand and load factor by only 1.2 percent and 40 million vehicles in 1990 would increase these quantities by only 2.9 percent. These potential additional energy demands are smaller than the probable errors of estimate of future demand and would require essentially no additional capacity, assuming the electro-chemical regeneration process is accomplished in off-peak periods. (However higher load factors might cause some shifts in the capacity mix.) there would be additional fuel requirements, principally coal. The overall impact of these numbers of electric vehicles on utility investment capital would be small, because capacity requirements are not signficantly different. There would be an increase of a few percent in pollution emissions from coal fired plants corresponding to the increase in total generation.

Overall, electric vehicles would be a welcome development for the electric power industry because of their ability to improve revenues with almost no increase in facilities. They appear likely to be a much smaller factor in future electric power growth than electric heating, for example, and would require only minor changes in utility plans.

Question No. 3. As indicated in the response to Question No. 1, the national average electric utility capacity factor and load factor will be increased by 0.12 percent for each one million electric vehicles. That is, the presently forecast 1980 national capacity factor of approximately 46.3 percent would be increased by .055 for each one million electric vehicles.

The increased generation costs for electric vehicles will consist almost entirely of fuel and direct operating costs. In 1975, the average incremental cost for coal fired generation is approximately 1.0 cents per kilowatt hour and for oil fired generation is approximately 2.3 cents per kilowatt hour. On the basis of a 3 to 1 ratio between coal fired and oil fired generation, the average incremental costs for electric vehicle generation in 1975 would be approximately 1.33 cents per kilowatt hour. For one million vehicles using 3.25 million megawatt hour a year, the energy costs would be approximately $43 million.

Total electric utility revenues in 1975 are estimated to be about $48 billion for sales of approximately 1750 million megawatt hours, resulting in an overall average cost of electricity in 1975 of about 2.7 cents per kilowatt hour. An addition of one million electric vehicles in 1975 would increase the generation by 3.25 million megawatt hours and direct costs by $43 million. Were the aggregate charges to customers to be increased by only the amount of the direct costs of electric vehicle energy, the average cost of electricity would be reduced by .0026 cents per kilowatt hour. However, in practice, the very small energy addition represented by the first one million vehicles would be billed to electric vehicle users at the standard rates and would serve to slightly improve the utility rates of return. If electric vehicles became a major load consideration and significantly improved load factors, the rate of return limits imposed by regulatory bodies would cause a readjustment in rates and a reduction in average bills approximately proportioned to the reduction in the aggregate cost per kilowatt-hour of providing electricity.

Even 40 million electric vehicles in 1990 will increase total electricity production by only about 3 percent, so the overall impact of electric vehicles on electric rates will be very small.

Question No. 4. Most water used by electric generating plants is returned to the body of water from which it was withdrawn, where it is available for other uses. The consumptive use of water by power plants is approximately 0.11 cubic feet per kilowatt hour. Thus, each one million electric vehicles would cause the consumption of about 360 million cubic feet of water per year.

Water consumption is proportioned to energy produced, so that 10 million vehicles in 1980 would increase the industry's water consumption by slightly

over one percent and 40 million vehicles in 1990 would increase water consumption by about 3 percent.

PACIFIC GAS AND ELECTRIC CO.,
San Francisco, Calif., September 30, 1975.

Hon. FRANK E. MOSS,
Chairman, Subcommittee for Consumers, U.S. Senate, Committee on Commerce, Washington, D.C.

DEAR SENATOR MOSS: This is in response to your letter and questionnaire relating to S. 1632 and H.R. 8800 which concerns a Federal program of research, development and demonstration designed to promote electric vehicle technologies.

It has been explained to Mr. Jaffe of your staff that Pacific Gas and Electric Company does not have meaningful national data to respond to these questions. At his request, we have translated the questions to the PG and E service territory and assumed that five percent of the one million proposed national vehicles would be in our service territory. Our attached questionnaire is based on this assumption.

Sincerely,

JOHN F. BONNER.

Attachment.

QUESTIONS CONCERNING S. 1632 AND H.R. 8800

Question No. 1. Electric vehicle use will, to some extent, reduce oil imports since many central station power plants use non-petroleum fuels (coal and nuclear). Estimate the reduction in petroleum imports per 1 million electric vehicles replacing internal combustion engine cars, based on a national mix of fuels used to fire central station power plants.

Question No. 2. What are the implications for the utility industry with regard to generating capacity, investment capital, and pollution control, of widespread use of electric vehicles? Please identify any assumptions used to answer this question. What other implications does widespread electric car use have for utilities?

Question No. 3. What is the estimate of the projected increase in the national average electric utility capacity factor per 1 million electric cars in operation? How should this increase in capacity factor translate into a reduced average power cost to the nation?

Question No. 4. Water requirements for central station power plants are several times greater than they are for gasoline production per unit of output energy. Thus, substitution of electric cars for internal combustion cars will involve substantially greater water use. How serious is this problem likely to be?

RESPONSES TO QUESTIONS CONCERNING S. 1632 AND H.R. 8800 FOR PACIFIC GAS AND ELECTRIC COMPANY'S SERVICE TERRITORY FOR 50,000 VEHICLES

Question No. 1. Some reductions in petroleum imports should occur in the Pacific Gas and Electric Company's territory. The amount is difficult to accurately predict, depending upon the type and use of gasoline vehicle displaced by 50,000 electric vehicles. Actual use is highly sensitive to the gasoline consumption (miles per gallon) of the existing gasoline vehicles. This could vary from 135,000 barrels of oil saved annually to a high of 877,000 barrels for our service territory.

Our recent test with 30 electric U.S. Postal Service vehicles at Cupertino, California indicates the electric vehicle will save 10,707 BTU/mile. This occurs because the gasoline jeep used 6.5 miles per gallon, and we generated over half of our kwh from hydro, atomic or geothermal.

If electric vehicles replaced this very low miles per gallon type vehicle, they would offset the use of 878,000 barrels of oil per year, assuming 10,000 miles per year use of the vehicle.

Using 12 miles per gallon, and 10,000 miles driven per year, and 50 percent fossil fuel for our system, the net saving of oil would be 135,000 barrels.

See Appendix A for details.

Appendix A

COMPARISON CALCULATIONS, GASOLINE VERSUS ELECTRIC VEHICLES

Gasoline=113,000 Btu/gal
Refinery—12% to produce gasoline from crude oil @ Standard Oil

$$\text{Heat energy per gallon at the refinery} = \frac{113{,}000}{.88} = 128{,}400 \text{ Btu/gal}$$

Gasoline

A. Reported 6.5 mpg for start-stop and idling in city driving=1 mi/0.1538 gal

$$\text{Equivalent KWH/mi} = \frac{0.1538 \text{ gal} \times 128{,}400 \text{ Btu/gal}}{3413 \text{ Btu/KWH}} = \underline{5.786 \text{ KWH/mi}}$$

(19,748 Btu/mi)

B. Assume 12 mpg in city driving=0.0833 gal

$$\text{Equivalent KWH/mi} = \frac{0.0833 \text{ gal} \times 128{,}400 \text{ Btu/gal}}{3413 \text{ Btu/KWH}} = \underline{3.134 \text{ KWH/mi}}$$

(10,695 Btu/mi)

Gasoline Engine—@ 12 mpg

$$0.0833 \text{ gal} \times 128{,}400 \text{ Btu/gal} = \underline{10{,}695 \text{ Btu/mi}}$$

Electric Generation "Mix"=2.649 KWH/mi
2.649 KWH/mi × 3413 Btu/KWH=<u>9,041 Btu/mi</u>
Savings from electric generation=10,695 Btu/mi−9,041=<u>1,654</u> Btu/mi
Assume 50,000 vehicles×10,000 mi/yr=500,000,000 mi
$5 \times 10^8 \times 1{,}651$ Btu/mi=825,500,000,000 Btu

$$\frac{8255 \times 10^8 \text{ Btu}}{610 \times 10^4 \text{ Btu/bbl}} = \underline{135{,}000 \text{ bbls/yr}}\text{—Savings}$$

Gasoline engine consumption—@ 6.5 mpg

$$0.1538 \text{ gal} \times 128{,}400 \text{ Btu/gal} = \underline{19{,}748 \text{ Btu/mi}}$$

Electric Generation "Mix"=2.649 KWH/mi

Electric vehicle—2.649 KWH/mi
(Mix Generation)

@ 1.3 KWH/mi at charger (Harbilt Mail Truck)

2.649 KWH/mi×3413 Btu/KWH=<u>9,041 Btu/mi</u>

	Btu/mi
Gasoline engine	19, 748
Electric vehicle	9, 041
Savings with electric vehicle	10, 707

$$50{,}000 \text{ vehicles} \times 10{,}000 \text{ mi/yr} = 500{,}000{,}000 \text{ mi}$$

$$5 \times 10^8 \text{ mi} \times 10{,}707 = 5{,}353{,}500{,}000{,}000 \text{ Btu}$$

$$\frac{53535 \times 10^8 \text{ Btu}}{610 \times 10^4 \text{ Btu/bbl}} = \underline{877{,}623 \text{ bbls/yr}}\text{—Savings}$$

Question No. 2. To study the electric vehicle as an electric load, we must consider power, energy and load factor. For load factor, we assume most people will connect the charger overnight. To generate electrical energy for 50,000 electric vehicles (approximately 5 percent of national average) is extremely small in comparison to our system peak of over 12 million kw. We have analyzed the State of California Division of Highways hourly traffic load data for various highways. Figure 1 is a composite of four locations in the San Francisco Bay Area. This traffic load curve is shown as a solid line. Over this curve is PGandE's typical daily load curve in kw demand. It will be noted that the highway traffic generally follows the electric demand during the day and night. In analyzing the time relationships for when a vehicle could be charged, the peaks must be

offset by approximately 30 minutes as the traffic sample points are approximately 30 minutes from the commuters' homes.

We have generally concluded that if electric transportation becomes widespread and people retain their existing driving habits, electric vehicles will not present a load that would require the addition of new generating facilities for many years. Some on-the-road vehicles will undoubtedly be connected during the peak periods, however, it should be a negligible percentage.

With our extensive hydro, geothermal and atomic energy sources, we don't foresee any unusual pollution control problems related to the electric energy generated for electric vehicles.

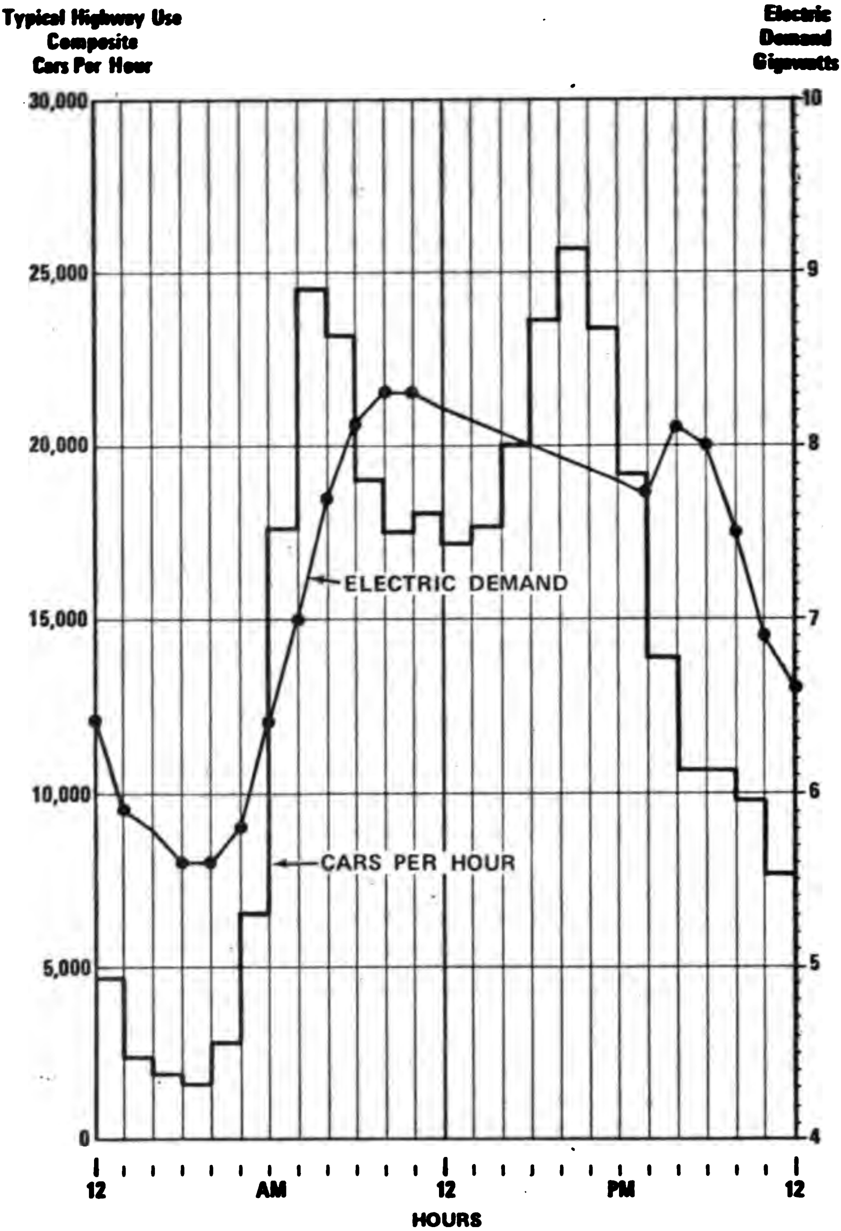

FIGURE 1. Typical highway use curve of metropolitan San Francisco bay area and electric demand of PG&E.

Question No. 3. Off-peak charging of 50,000 vehicles driving 10,000 miles annually would add approximately 6.5 billion kwh to our annual production of 60.9 billion in 1974. This would increase our annual load factor from 59.7 to h ~~ever~~, this again is very sensitive to the type of service the electric for and represents a maximum figure. If the electric vehicle is as a second family car or put into route type delivery service (15 miles per at about 4,000 miles per year would use about 2.6 billion kwh per year would only raise this load factor to 62.

With this wide change in load factor possible and due to other conditions that affect annual load factor, it is difficult if not impossible at this time to comment in a quantitative manner on any translation to reduced average power costs.

Question No. 4. Water use again varies in the ultimate use of the fuel. Data from a modern 164,000 barrel per day refinery reveals 1,700 gallons per minute for process water or .357 gallon of water per gallon of gasoline. At 12 miles per gallon .0298 gallon of water is used per gasoline engine mile driven.

Electricity generated in a modern 750 megawatt thermal plant will require about 50 gallons per minute of makeup water or .0046 gallon per kwh. At 1.4 kwhr/mile .0056 gallon of water is used per electric mile driven.

Thus, about 12,100,000 gallons of high quality process water are saved annually through the use of 50,000 electric vehicles at 10,000 miles per year.

In both cases the refinery and electric plant use large amounts of cooling water which is primarily from the Pacific Ocean and losses in these systems (8,000 gallons per minute refining 7,000 gallons per minute 750 megawatt unit) have been ignored as the ocean water is of no value.

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